

Marine Transportation and Aquatic Invasive Species:
Comparing Hawaii and Washington Policy

by
Patricia Hildebrandt Bateman

A Thesis: Essay of Distinction
Submitted in partial fulfillment
of the requirements for the degree
Master of Environmental Studies
The Evergreen State College
March 2011

©2011 by Patricia Hildebrandt Bateman. All rights reserved.

This Thesis for the Master of Environmental Studies Degree
by
Patricia Hildebrandt Bateman

Has been approved for
The Evergreen State College
By

Martha L. Henderson, Ph.D.
Member of the Faculty

Date

ABSTRACT

Marine Transportation and Aquatic Invasive Species: Hawaii and Washington Policy Comparison

Patricia Hildebrandt Bateman

Aquatic invasive species have detrimental economic and environmental impacts for both the private and public sectors. Research has found that the main vector for the transmission of aquatic invasive species is marine transportation, through ballast and hull fouling. States have attempted to address the issue of marine transportation and invasive species through policies and regulations, however, inconsistencies and gaps make successfully combating aquatic invasive species nearly impossible. This comparative policy analysis addresses the differences between two states, Washington and Hawaii, whose economies include a high degree of interstate transportation, yet have varying policies regarding ballast and hull fouling. Washington and Hawaii policies have strengths and weaknesses, however, have different compliance and success rates. This policy analysis identifies similarities and differences between the two states, as well as current national and international regulations. Finally, policy improvements are suggested to help reduce the transmission of aquatic invasive species to and from both locations, placing an emphasis on the importance of consistency when battling a national and international issue.

Contents

- 1: Introduction
- 2: Marine Transportation Components of Concern
 - 2.1: Ballast
 - 2.2: Hull Fouling
- 3: Current Management
 - 3.1: Ballast
 - 3.1.1: Filtration
 - 3.1.2: Open Ocean Exchange
 - 3.1.3: Treatment Technologies
 - 3.2: Hull Fouling
 - 3.2.1: Anti-Fouling Coatings
 - 3.2.2: Manual Removal
- 4: Current Regulations
 - 4.1: State
 - 4.1.1: Ballast
 - 4.1.2: Hull Fouling
 - 4.2: National
 - 4.2.1: Ballast
 - 4.2.2: Hull Fouling
 - 4.3: International
 - 4.3.1: Ballast
 - 4.3.2: Hull Fouling
- 5: Bi-state analysis of Current Practices and Regulations
 - 5.1: Ballast
 - 5.2: Hull Fouling
- 6: Suggested Improvements
- 7: Conclusion

Figures & Images

- 2.1: Ballast Loading and Discharge Patterns
- 3.1.3: Treatment Options
- 4.1: Washington and Hawaii Regulations Comparison Chart
- 4.2.1: Exclusive Economic Zones of the United States
- 4.3.1: Treatment Standards Comparison Chart

Acknowledgments

I would like to thank the people who have helped and inspired me while working towards the completion of my thesis and the Master of Environmental Studies degree.

Thank you to my reader and MES director, Martha Henderson, who guided me through the thesis process and helped me stay on track. She provided me with valuable insights and support. Thanks are also due to Gail Wootan, the MES Assistant Director, who helped keep myself and other students on track when working towards the goal of graduation.

Many thanks are also owed to my supportive family and friends. You made sure I completed this thesis, and I appreciate the love and support. A special thanks to my husband, Matthew, who helped me recognize when I needed to stay focused, and who inspires me to want to make the world a better place for our future, and the future of those we share this world with.

Thank you.

1: Introduction

The transmission of aquatic invasive species due to marine transportation, both commercial and private, has become an increasingly important question in environmental management over the past decades. Aquatic invasive species have a significant impact on the environment and related ecosystems and ecosystem services; however, the transmission of aquatic invasive species is almost entirely anthropogenic. The anthropogenic nature of this transmission leads to the need for an anthropogenic solution, policy. Policy has been established by several governments to address aquatic invasive species and marine transportation, however, there is a lack of collaboration.

Increased international trade and ship transportation has contributed to multiplied organism discharge in ports throughout the world, with approximately eighty percent of the world's trade volume transported via ship (National Research Council 22), and large vessel capacities in excess of 200,000 m³ of ballast (National Research Council 23). It is estimated that 438 million m³ of wetted surface area, also known as the portion of the boat or vessel surface located under water, enters the United States yearly (Smithsonian Environmental Research Center 1). Globally, it is estimated that more than 100,000 marine species are transported each day via ballast (Buck 1). Several preventative measures are currently being studied to help prevent the introduction of invasive species, but the United States' and other global shipping leaders' lack of a comprehensive ballast and hull fouling management plan is problematic. This paper discusses current ballast and hull fouling management approaches by comparing Washington and Hawaii policies and makes suggestions

for improving these policies to help reduce the transmission of Aquatic Invasive Species.

Aquatic invasive species, also known as AIS, have both environmental and economic impacts for the planet, governments, and private industry. It is clear that aquatic invasions have created changes in food web dynamics, chemical cycling, disease outbreaks, and species extinction rates. Invasive species are second only to habitat loss in terms of risk to overall global biodiversity (Gramling 8). The rate of known marine invasions in North America has increased exponentially over the past two hundred years (Carlton et al 3). Not only is the number continuing to rise, there is also an increase in the variety of species being transported, the types of habitats they infest, and the global regions they are impacting. The Great Lakes have seen over sixty new invasive species since 1960 and San Francisco Bay over seventy since 1970 (Gramling 8).

Economic impacts of invasive species include fishery losses, drop in tourism, damage to municipal water systems, as well as the money spent for eradication of invasive species. In 2001, it was estimated that the U.S. alone suffered over \$100 billion per year in economic losses due to invasive species (National Ballast Information Clearinghouse 1).

A prime example of environmental and economic loss due to AIS is the case of the zebra mussel and the Great Lakes, which created an impetus for the Invasive Species Act. The zebra mussel, an import from the Black Sea, began establishing itself in the Great Lakes in 1988. Since then, the mussel become established north to Quebec, south to New Orleans, and as far west as Oklahoma, with small

infestations as far west as Oregon and Washington. The mussels are inedible to most of North America's indigenous species, consequently allowing their rapid proliferation into massive colonies and strangling native ecosystems. The muscle clogs industrial and municipal water pipes causing closures to accommodate manual removal. The mussels filter out phytoplankton at a high rate, changing entire ecosystems they inhabit. It has been estimated zebra mussels cost the United States \$5 billion each year in economic losses and control efforts (Harder 234).

While comparing AIS policies for Washington and Hawaii may not seem intuitive due to differing climates, comparing the two states offers an excellent opportunity to examine how marine transport in different environments can result in dispersal and establishment of aquatic invasive species. The two states have economies that rely heavily on marine transportation, experiencing approximately 500 direct cargo interactions annually (Kaluza et al, 2172), resulting in high exposure to AIS, and reinforce the need for stringent and comprehensive policies regardless of origination and destination of travel.

Current research in the area of marine transportation, ballast, and hull fouling and the resulting invasive species infestations has not created a cohesive or thorough body of knowledge. It is widely accepted and supported that commercial trade results in rising annual and cumulative rates of invasion (Meyerson & Mooney 200). Current research focuses mainly on localized infestations, usually evaluating the situation on a local scale, rarely focusing on a nation wide or global scale. Detailed quantitative research has been limited and focused on invasion patterns rather than the impacts of the invasions (Meyerson & Mooney 202). However,

multiple efforts have been made to address increased concerns in regards to globalization, invasive species, and biodiversity threats.

Comparative policy analysis is lacking in current literature. The most comprehensive comparisons available have been located in presentation notes and conference proceedings, such as Jason Savarese's presentation at the 14th Biennial Coastal Zone Conference, entitled "Preventing and managing hull fouling: international, federal, and state laws and policies." Due to the lack of comprehensive comparisons, it is difficult to establish current comparison methodology, resulting in an increased need to provide a comprehensive source of current regulations impacting Washington and Hawaii prior to providing a specific comparison. Comparative analysis of current regulations will allow Washington and Hawaii, as well as surrounding states, to make educated decisions about comprehensive and effective policies, and help them to identify areas in which they can improve and collaborate. This thesis works to identify the similarities and differences, as well as suggest possible improvements to current policies.

2: Marine Transportation Components of Concern

In order to understand the relevance of aquatic invasive species and marine transportation, it is important to understand the different components of marine transportation that are integral in the transmission of invasive species. The main areas of concern are ballast and hull fouling. These two causes are defined here:

2.1: Ballast

Ballast is any solid or liquid placed in a ship to increase the depth of submergence of the vessel in the water, to change the trim, to regulate stability, or to maintain stress loads within acceptable limits. It may also be brought on board to compensate for drinking water or fuel consumption (Carlton et al 3) and may be sea water, fresh water, or suspended or settled sediments (National Research Council vii). Ballast is taken on at one port when the cargo is off-loaded by the vessel, and is usually discharged at another port when cargo is received, as seen in image 2.1 (Center for Coastal Resources 1).

Image 2.1: Ballast loading and discharge patterns.

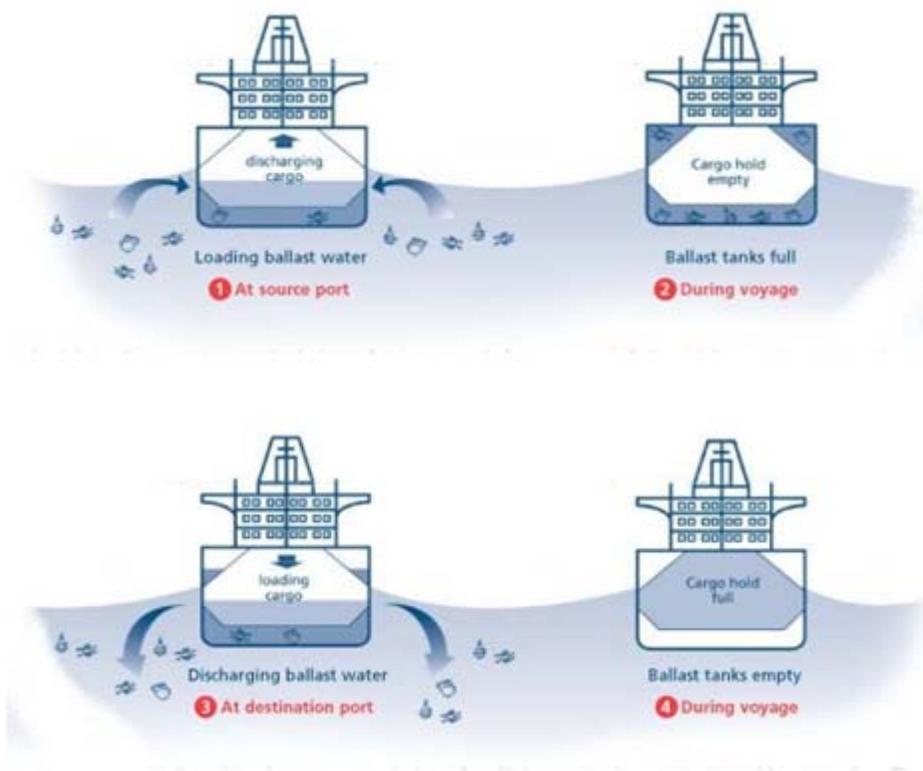


Image courtesy of the International Maritime Organization

Vessels take on ballast usually by pump or gravitation. On a vessel, intakes are located several meters below the water line, and are protected by a grate or strainer, equipped with openings between 1.0 and 1.5 cm in diameter (Gramling 6). Ballast tank configuration varies greatly from vessel to vessel, and may consist of several small tanks, or one large tank (National Research Council 25). When ballast water is brought on board a vessel, suspended sediment will settle to the bottom of the tank, and will likely not be discharged during the ballast water disposal or exchange. Settled sediments are also of concern in reference to AIS transmission, as resulting sediments from the tanks and holds of vessels are removed only on an intermittent basis through a variety of methods, either in-water or on shore. Prior to removal from the vessel they can create a viable substrate for organisms brought on board via ballast water, and result in a high level of organism survival and reproduction.

Ballast water that is brought on board a vessel when it is not carrying cargo contains organisms living in the surrounding waters and sediments, ranging in size from microscopic viruses to twelve inch fish (Globalballast 2002, 1). The size of surviving organisms varies depending on the uptake method, which can be gravitational or pump fed. Larger organisms tend to survive when gravitation is used exclusively to take on ballast, while larger organisms will die when passing through the pumping mechanisms (Carlton et al 5). Surviving organisms have the potential to become AIS (also referred to as bio-invaders, non-native species, alien species, or exotic species) in the port of ballast discharge. Research has shown that commercial

shipping may account for up to eighty percent of aquatic invasive species in coastal habitats. Up to 300 species have been identified in the ballast water of a single container ship (Dobroski 6). These include bacteria, microbes, small invertebrates, and the eggs, cysts, and larvae of various species. The problem of AIS transmission in ballast water is only compounded by the fact that virtually all marine species have life cycles that include at least one planktonic state (Globalballast 2002, 2) meaning species which are normally thought of as anchored can still be transmitted. Varying species and density of AIS are currently found worldwide. Widespread AIS include the North American Comb Jelly, the North Pacific Seastar, the Zebra Mussel, Asian Kelp, the European Green Crab, and the Mitten Crab (Globalballast 2008, 1).

2.2: Hull Fouling

Hull fouling is the settlement and accumulation of microorganisms, plants, algae, and animals on the underwater surface of a vessel or platform. Fouling organisms are organisms that attach to submerged hard surfaces, both natural and manmade. Fouling organisms include species such as mussels, seaweed, sea squirts, and anenomes, as well as the associated organisms that may live on these species—such as bryozoans, crabs, shrimp, and sea snails. The above listed organisms can create a fouling community that lives on the vessel and travels with it from port to port, allowing for the introduction of new AIS (Fofonoff).

There are many factors that relate to the dispersal of AIS and hull fouling. Factors that influence whether a vessel can successfully transfer AIS include vessel speed, harbor residence time, voyage duration, surface area and complexity of

vessel, and the period of time since the vessel was last painted. Vessel areas that do not experience wave action due to speed, such as the anchor and anchor chain, as well as the sea chest and propeller, also tend to accumulate fouling communities at a higher frequency than those that are exposed to higher wave action. Studies have documented extensive fouling communities particularly on towed vessels and recreational vessels (Takata, Falkner, and Gilmore). In Hawaii, it is believed that fouling is responsible for more successful marine introductions than any other vector, accounting for approximately seventy-four percent of all AIS introductions (Godwin). For North America, a study estimates that at least thirty-six percent of AIS introduced via maritime transportation was done via fouling (Fofonoff et al).

3: Current Management

Management of AIS by ballast and hull fouling can be split into two main approaches: technical control and regulatory control. Both play important roles in preventing AIS transmission, and it is important to understand technical control in order to be able to craft realistic policies and regulations.

3.1: Ballast technical control

Ballast water management (BWM) is a complicated issue with several components. Ballast water management refers to the techniques used to remove AIS from ballast. In order to establish a better understanding of BWM, the following sections will discuss currently used techniques for removal of AIS and techniques currently being tested.

3.1.1: Intake and Discharge Filtration

Ballast water can be filtered before it enters the vessel, or filtered during discharge. Filtering during intake is considered preferential because it allows the organisms which have been removed to remain within their native habitat, while organisms filtered out during discharge have to be disposed of properly so they do not accidentally contaminate the environment (Tang 412). Currently, filtration is occurring on a basic level during most ballast intake procedures. As was stated previously, the majority of vessels have a screen or grate on the ballast intake, in order to prevent the intake of any large organisms. Standard intake screens filter to the 1.0 to 1.5 cm level, which still allows for contamination by a multitude of organisms, including viruses and bacteria (Gramling 6). According to Congelosi et al (547), the decrease in opening size to 25 to 50 micrometers leads to effective removal of biological matter, including macro and micro-zooplankton.

3.1.2: Open-ocean ballast water exchange

Open-ocean ballast water exchange is currently the most common method of ballast treatment occurring worldwide. It is also the recommended method for the reduction in risk of introduction of AIS (Globalballast 2008). Ballast water exchange works in the following pattern: the vessel takes in ballast at port, travels to a certain offshore distance (at least 200 nautical miles) and depth (at least 2,000 meters) and exchanges the ballast in tank for open-ocean water (Globalballast 2008). Depending on trip length, this exchange can occur only once, or many times (Gramling 6). Open-ocean water is then released at the arrival port.

Exchange is effective for two main reasons: (1) the majority of organisms taken in by ballasting are suited to the brackish water often found in near-shore locations, and not to the higher salinity water of the open ocean, and vice versa. Releasing open-ocean organisms into the brackish near-shore water often results in a high death rate, as does releasing near-shore organisms into the open-ocean water (Globalballast 2008), (2) The density of organisms living in near-shore waters is significantly greater than the density of organisms in the open-ocean. Releasing open-ocean water at near-shore locations results in an overall drop in number of organisms released (Smithsonian Environmental Research Center). Offshore distance and depth of ballast exchange also helps to ensure the effectiveness of ballast exchange, due to a decrease in species density with increased depth (National Research Council 37).

There are two types of ballast water exchange: (1) Flow-Through and (2) Sequential. The choice of exchange method is dependent on the ballast tank configuration of an individual vessel (Prince Williams Sound Fact Sheet 6). Flow-through exchange involves pumping open ocean water into a full ballast tank for a length of time sufficient to flush the ballast water tank. Sequential is used on vessels with multiple ballast chambers, and involves completely emptying segregated ballast tanks, individually or in sequence, and then refilling them with open ocean water (Prince William Sound Fact Sheet 7).

3.1.3: Possible Ballast Treatment Technologies

Ballast water treatment can take place during different stages of the ballast process. These treatments may be either port-based or shipboard, and can take place at various stages in the vessel’s journey. There are three main shipboard treatment areas being researched and tested, and a fourth area being explored in port-based facilities.

Port-based treatment involves having a facility at each port equipped with the ability to either fill ballast tanks with previously treated water or to de-ballast tanks into land based treatment plant (Puget Sound Action Team 36). Shipboard treatments include mechanical options, such as filtration, de-oxygenation, ozonation, and cyclonic separation. Chemical use of biocides, chlorine, hydrogen peroxide, and sodium are also being tested at this time. Finally, the use of heat and electricity- such as UV radiation, magnetic, electrolysis, and ultrasonic – are also being tested (National Research Council 53-55).

Image 3.1.3: Treatment Options

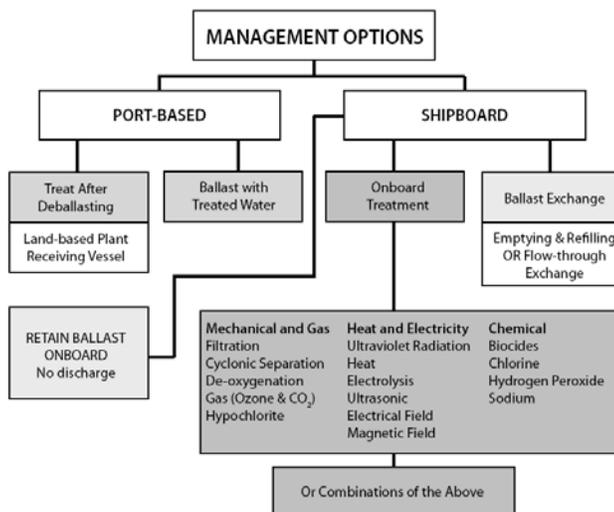


Image courtesy of Puget Sound Action Team

There are varying degrees of success with these methods, but with the technologies available at this time, it is currently considered likely that a combination of treatment techniques will need to be utilized in order to meet desired organism discharge standards (National Research Council 60). The lack of a universal treatment standard, which will be discussed in the next section on regulations, has also created an inability to successfully develop technologies, as an ultimate goal is not known at this point (U.S. Coast Guard 2004, 3).

There are several considerations to be included when evaluating ballast treatment techniques, beyond the ability to remove AIS. Such considerations are: environmental impact (such as discharge of chemicals), safety, implementation cost, and loss of transit time (National Research Council 57). The cost of implementation is especially limiting when new treatment techniques need to be tested at the full scale level (Globalballast 2008). Currently, very few vessels have full scale shipboard testing occurring.

3.2: Hull fouling technical control

Hull fouling is controlled through the use of two common methods: anti-fouling paint or manual removal. Both methods are discussed below.

3.2.1: Anti-fouling paint

Due to the fact that fouling can be detrimental economically to the shipping industry, preventing fouling for the purpose of vessel maintenance and efficiency has been of high importance for many decades. Anti-fouling compounds have

included arsenic, lime, mercury, and pesticides (Lewis). Currently, the most commonly used technique to prevent hull fouling is the use of biocidal paint, which slowly release tributyltin (TBT), an organotin based chemical. By the mid 1970's most oceangoing vessels had TBT based anti-fouling paint, as the compound was found to be highly effective at keeping the hull clean. However, studies have shown that TBT may have significant environmental impacts. These studies indicate that the slow release of TBT to the vessel hull also results in the slow release of the chemical to the water column sediments, and has been linked to shell deformation in oysters, reduced infection resistance in fish, and is a bioaccumulate in the food chain (Nehring 343).

As a result of these findings, many countries have implemented rules and regulations restricting the use of TBT based anti-fouling paint. Due to these restrictions there has been an increased use of Copper and Zinc based paints for anti-fouling, however, several countries and states, including Washington, have regulations limiting the use of such products. Currently the only viable, environmentally friendly fouling prevention option is the use of silicon-based coatings that result in the vessel hull being too slippery for organisms to adhere, however, this process is not cost effective at this point in time (Takata, Falkner, and Gilmore 4).

3.2.2: Manual Removal

In addition to biocidal paints, hull fouling is controlled by the regular manual removal of organisms from the vessel. Vessels are cleaned during any period of dry

dock, but also may be cleaned while still in water. In-water cleaning has become a topic of concern for multiple reasons. First is that in-water cleaning may result in an increased sloughing of TBT based paints, increasing water pollution issues. Second is the concern that fouling organisms which are being manually removed are still viable in the environment they are being disposed in. Studies have shown that upwards of seventy percent of organisms removed from hulls are still viable in the port where they are removed, which likely is not their port of origination. Due to this issue, in-water cleaning may be resulting in increased AIS dispersal rates (Takata, Falkner, and Gilmore 14). In addition, hull scraping can leave remnants of the fouling organisms, such as shells or tissues, which in some fouling species act as a signal for unattached organisms in the water column to settle (Railkin 256).

4: Current Regulations

There are several regulations that impact ballast and hull fouling practices. The problem of AIS transport via ballast and hull fouling is not just a local problem, so many state, federal, and international laws have been implemented which impact practices. While this paper is primarily concerned with Washington and Hawaii, it is important to understand that maritime travel is international, and international, national, and state policies have various impacts.

4.1: State

Washington and Hawaii have greatly varying climates and oceanic environments. Washington's outer coast lines as well as the Puget Sound region are

classified as temperate cold, with an average nearshore water temperature ranging from 44 degrees Fahrenheit in winter months to 56 degrees Fahrenheit in the summer months (NOAA). Washington has 3,026 miles of tidal shoreline, and is home to multiple active ports (NOAA).

Hawaiian waters are classified as tropical, with nearshore water temperatures ranging from 71 degrees Fahrenheit during winter months to 80 degrees Fahrenheit in the summer (NOAA). Hawaii consists of eight major islands, four of which (Hawaii, Oahu, Maui, and Kauai) are large enough to house commercial ports, that come together to create what is known as the Hawaiian archipelago. According to NOAA tidal shoreline calculations, Hawaii has 1,052 miles of tidal shoreline.

The Hawaiian archipelago is about 4,000 km from the nearest continent, making it the most isolated group of oceanic islands in the world. It also possesses one of the most highly endemic and endangered biotas on earth, and is home to approximately 40% of the threatened and endangered species in the United States. Hawaii is also a major transportation hub and tourist destination. The remote location, highly sensitive environment, and status as a transportation and tourist destination make it exceptionally susceptible to AIS from marine transportation. According to the Hawaii Biological Survey by the Bishop Museum, Hawaii is home to 343 total aquatic invasive species, 287 invertebrates, 24 microalgae, 12 flowering plants, and 20 fish. Of these 343 total species 251 are a direct result of marine transportation, either through ballast water, solid ballast, or hull fouling.

4.1.1: State Ballast

Currently, the legislatures in the states of California, Hawaii, Maryland, Michigan, Oregon, Virginia, and Washington have enacted laws addressing ballast water discharge. California, Hawaii, Michigan, and Washington have laws more stringent than those laid out in the National Invasive Species Act (NISA), while others do not significantly differ from NISA (American Association of Port Authorities 2). This paper is concerned specifically with the policies of Washington and Hawaii, and details of both follow.

Washington has enacted RCW (Revised Code of Washington) 77.120, the Ballast Water Control Act. This RCW specifies that discharge of ballast water is only permitted in Washington State with authorized permission, if an open ocean exchange has occurred, any alternate treatment methods on board have been previously approved, or that have ballast on board that originated within the waters of Washington, the Columbia river system, or the internal waters of British Columbia south of latitude fifty degrees north.

In order to enforce RCW 77.120, there is WAC (Washington Administrative Code) 220-150, which is the Ballast Water Discharge Standard and Treatment System Approval Process. The WAC states that vessels that have not adequately exchanged their ballast as required by RCW 77.120 must treat their ballast to meet or exceed the state discharge standards, however, those standards have not been set and the proposed standards are currently withheld from WAC records. WAC 220-150 states that vessels must report ballast water management information and plans to discharge at least twenty-four hours prior to entering Washington waters

by submitting a ballast water reporting form, either the International Maritime Organization or United State Coast Guard version, electronically transmitted to Washington State Fish and Wildlife.

If vessels do not meet the above standards by filing a ballast water reporting form, retaining ballast water, exchanging ballast water, or treating water, they may be fined up to \$27,500 a day for each violation (Washington State Department of Fish and Wildlife). Washington does allow for safety exemptions from the above rules, however, a \$500 safety exemption filing fee is assessed to cover administrative costs to assess compliance.

In 2001, Hawaii state legislature designated the Department of Land and Natural Resources to be the lead agency in preventing the introductions of AIS through the regulation of ballast water discharges and hull fouling via Hawaii Revised Statues Chapter 187A-31. After this designation, the Department of Land and Natural Resources created Hawaii's Ballast Water and Hull Fouling Alien Aquatic Organism Prevention Program. This prevention program was broken into two phases, phase I relating to ballast water, and phase II relating to hull fouling. Phase I sets forth proposed administrative rules, many of which were incorporated into Department of Land and Natural Resources Chapter 13-76, explained below. The suggestions of this plan included: requiring a mandatory ballast management plan on board all vessels entering state waters, required mid-ocean ballast water exchange with required reporting to the Department of Land and Natural Resources 48 hours prior to entering state marine waters, and required ballast water sediment management plan on board all vessels entering state waters.

Hawaii's current ballast water practices are laid forth in Hawaiian Administrative Rules, Department of Land and Natural Resources Chapter 13-76. This administrative rule was put into place in August of 2007, and strengthened Hawaii's previously weak policy on ballast water management. Chapter 13-76 requires that all vessels have a ballast water management plan on board, as is also required by the United States Coast Guard. Hawaii also requires a complete ballast water exchange outside of the Exclusive Economic Zone (200 nautical miles off shore), and must submit a ballast water reporting form to the Department of Land and Natural Resources and the United States Coast Guard, following Coast Guard standards, at least 24 hours prior to arrival within Hawaiian waters. This reporting can be done electronically or via fax, and the reporting form must be kept on board for two years. Chapter 13-76 clearly states that it is unlawful for the vessel master to prevent, hinder, or interfere with the Department of Land and Natural Resources or the United States Coast Guard's evaluation of the vessel's compliance to any of the above mentioned requirements.

Vessels are exempt from the ballast water exchange requirements in Hawaii if there is a safety risk associated with completing an exchange, if they have a United States Coast Guard approved water treatment system on board, if it is a vessel of the United States Coast Guard or the Department of Defense, or if the vessel is discharging water in the port of origin of the ballast.

4.1.2: State Hull

Washington State does not have any laws or regulations related to preventing AIS via hull fouling. However, Washington does have regulations relating to anti-fouling paints and boat cleaning processes related to removing fouling organisms.

Washington regulations, explained below, are water quality based and aim to prevent the release of toxic chemicals into the environment, but have an impact on AIS transmittal as well.

RCW 90.48.080 states that it is illegal for “any person to throw, drain, run, or otherwise discharge into any of the waters of this state, or to cause, permit or suffer to be thrown, run drained, allowed to seep or otherwise discharged into such waters any organic or inorganic matter that shall cause or tend to cause pollution of such waters”. Washington State has interpreted this to mean it is illegal to perform underwater cleaning of hulls that have ablative (soft and toxic) paints, and the related fine can be up to \$10,000. Washington also asks vessels to rinse visible organisms from anchors and anchor chains prior to entering Washington State waters; however, this is not an enforced activity.

Hawaii does not have any current laws or regulations related to hull fouling, either for AIS or water quality reasons. The previously mentioned Ballast Water and Hull Fouling Alien Aquatic Organism Prevention Program, phase II, was designed with hopes of making policy suggestions aimed at hull fouling. Phase II of the prevention program was not completed, and the Department of Land and Natural Resources of Hawaii has stated that budget restrictions are the main obstacle preventing further development and enforcement of hull fouling regulations

(Showalter 10). Hawaii does house some of the most advanced and up-to-date research on hull fouling, funded by the Bernice Pauahi Bishop Museum in conjunction with the University of Hawaii. The advanced knowledge Hawaii has about their hull fouling situation and resulting AIS infestations lends itself well to making thorough policy decisions.

Both ballast and hull fouling regulations for Washington and Hawaii are summarized in Figure 4.1, allowing for quick comparison of the two states.

Figure 4.1: Washington and Hawaii Regulation Comparison Chart

Area	Washington	Hawaii
Reporting Requirements (Ballast)	24 hours prior to entering Washingtonian waters.	24 hours prior to entering Hawaiian waters.
Exchange Requirements (Ballast)	Open Ocean exchange required, outside of EEZ, except when coming from Washington, the Columbia river system, or the internal waters of British Columbia.	Open-ocean exchange required, outside of EEZ, except for vessels conducting interisland travel only.
Discharge Standards (Ballast)	Previously proposed Washington goals: Technology to inactivate or remove 95% of zooplankton & 99% of bacteria and phytoplankton	No state discharge standards, no proposed discharge standards.
Exemptions (Ballast)	Safety, military, treatment system on board	Safety, military, treatment system on board
Paint (Hull)	Copper discharge limits from dry-docks-established in permitting process	No regulations
Cleaning (Hull)	No in-water cleaning, Vessels asked to rinse visible organisms from anchors and anchor chains	No regulations

4.2: National Regulations

National regulations impact state regulations for many reasons. In the case of ballast water and hull fouling, it is written that state regulations must meet or exceed national regulations. Below are the minimum requirements for Washington and Hawaii and laid forth by national policy.

4.2.1: National Ballast

The first attempt to control AIS in the United States was the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, referred to as NANPCA, which established a federal program to prevent the introduction and control the spread of unintentionally introduced AIS. The creation of NANPCA was brought on by the destruction seen in the Great Lakes by the Zebra Mussel. The responsibilities of implementing NANPCA were spread among the U.S. Coast Guard, the EPA, U.S. Fish and Wildlife Services, Army Corps of Engineers, and NOAA, who worked together to form the Aquatic Nuisance Species Task Force (Buck 4). The task force is responsible for conducting studies and reporting to Congress in order to (1) identify areas where ballast water exchange can take place without causing environmental damage, and (2) determining the need for controls on vessels entering U.S. waters other than the Great Lakes (NANPCA). Under this act, the Coast Guard is also responsible for developing and implementing a ballast water management program to prevent the unintentional introduction and dispersal of AIS. NANPCA also encouraged the Secretary of Transportation (later changed to the Secretary of Homeland Security) to

negotiate with foreign countries, through the International Maritime Organization, in order to establish similar international prevention and control goals (Buck 4).

The National Invasive Species Act of 1996, referred to as NISA, reauthorized and amended the NANPCA (Buck 4). NISA created a national ballast water management program modeled after the Great Lakes program, wherein all ships entering U.S. waters (only after operating outside of the U.S Exclusive Economic Zone, see image 4.2.1), are directed to undertake mid-ocean ballast exchange or alternative measures pre-approved by the U.S Coast Guard.

Image 4.2.1: Exclusive Economic Zones of the United States

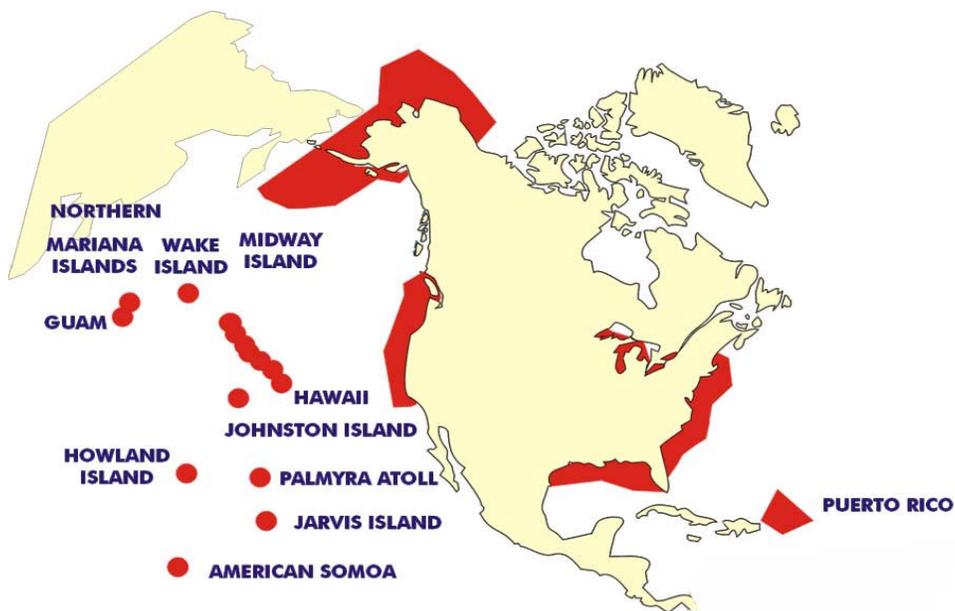


Image courtesy of NOAA

The Coast Guard is not required to enforce exchange or treatment on a ship-to-ship basis based on NISA, but was instead asked to study the compliance rates on a voluntary basis (Buck 5). Compliance rates are currently measured by the National

Ballast Information Clearinghouse, which was developed jointly by the Coast Guard and the Smithsonian Environmental Research Center. Following the first three years of compliance studies, if non-compliance rates were significant, the exchange or treatment program was to become mandatory (NISA).

NISA created a Ballast Water Demonstration Program, established to promote research and development of ballast water treatment technologies to be used as an alternative to exchange. NISA also required the Coast Guard to study and report to Congress on the effectiveness of currently used port-based treatment facilities found in Alaska, in addition to completing studies on the impacts of AIS in Lake Champlain, Chesapeake Bay, San Francisco, Honolulu Harbor, and the Columbia River System. Like NANPCA, NISA also encouraged negotiations with international governments in order to establish similar goals and regulations (NISA).

As was previously noted, NISA required the establishment of a Ballast Water Demonstration Program, which came to fruition as the Coast Guard STEP Program, which is a Shipboard Technology Evaluation Program that aims to promote research and development of new technologies. STEP facilitates the installation of experimental technologies on both foreign and domestic vessels. Regulatory incentives would grant conditional equivalencies for participatory vessels that might not meet discharge standards if they were to become mandated by future regulations (U.S. Coast Guard 2001, 7).

4.2.2: National Hull

On the federal level, the U.S. Coast Guard is the agency responsible for addressing hull fouling. The Coast Guard has always addressed hull fouling via yearly vessel inspections, but the federal mandatory ballast water program mentioned above directs vessel owners to remove fouling organisms. The program states that “Masters, owners, operators, or persons-in-charge of all vessels equipped with ballast water tanks that operate in the waters of the U.S. must do the following: Rinse anchors and anchor chains when you retrieve the anchor to remove organisms and sediments at their place of origin, and remove fouling organisms from hull, piping, and tanks on a regular basis and dispose of any removed substances in accordance with local, state, and federal regulations (Showalter 3).

4.3: International Regulations

International shipping regulations are designed and enforced by the International Maritime Organization. The International Maritime Organization, commonly known as the IMO, is a specialized agency of the United Nations with 167 member states, and is based in the United Kingdom. The IMO’s main task is to develop and maintain a comprehensive regulatory framework for shipping, and includes safety, environmental concerns, legal matters, technical co-operation, maritime security, and the efficiency of shipping (IMO 2008).

The IMO conventions discussed below are not ratified by the United States, and therefore do not regulate activities within Washington and Hawaii. However,

states often refer to these conventions as the ultimate goal when drafting their own policies.

4.3.1: International Ballast

After fourteen years of negotiations, the International Maritime Organization adopted the International Convention for the Control and Management of Ship's Ballast Water and Sediments on February 13th 2004.

The International Convention for the Control and Management of Ship's Ballast Water (hereafter the BWM Convention), includes 22 articles which provide the following information:

- Member states have the right to take more stringent measures for protection than laid out in the BWM Convention, but should ensure more stringent standards do not cause greater harm than they prevent to their environment, human health, property or resources, or those of other states.
- Member states are to ensure that ports and terminals where cleaning or repair of ballast tanks occurs have adequate reception facilities for sediments.
- States should work to promote and facilitate scientific and technical research on ballast water treatment technologies.
- Vessels are required to have on board and implement a Ballast Water Management Plan approved by the regulating administration, which must include a detailed description of actions to be taken to implement the management plan requirements.

- Vessels must have on board a Ballast Water Record Book, which records when ballast water is taken on board, circulated or treated for BWB purposes, and when it is released to sea. This record book must remain on board for two years after final date recorded.
- Vessels are required to be surveyed and certified, and may be inspected at anytime to verify that the ship has a valid certificate, to sample ballast water, or to inspect the vessel’s ballast water record book.
- States should provide technical assistance to train personnel; ensure the availability of relevant technology, equipment and facilities; and other actions aimed at the effective implementation of the Convention.

The BWM Convention also lays out specific discharge and treatment standards, known as the Ballast Water Performance Standards. These standards are laid in image 4.3.1, in comparison with United States Coast Guard Standards.

Image 4.3.1: Treatment Standard Comparison Chart

	IMO Regulations	NISA Regulations
Standard	Discharge Standards	Exchange Standards
1) Organisms greater than 50 microns in dimension	<10 viable organisms per cubic meter	USCG will propose numeric discharge and treatment standards at a future time
2) Organisms 10-50 microns in minimum dimension	<10 viable organisms per ml	No Standards
3) Organisms less than 10 microns in dimension	No Standards	No Standards
4) <i>E. Coli</i>	<250 cfu/100 ml	No Standards
5) Intestinal <i>Enterococci</i>	<100 cfu/100 ml	No Standards
6) Toxigenic <i>Vibrio cholerae</i>	<1 cfu/100 ml	No Standards

According to the BWM Convention, the above requirements and standards will enter into force 12 months after ratification by 30 States, representing 35% of world merchant shipping tonnage. As of January 28, 2011 28 countries (Albania, Antigua and Barbuda, Barbados, Brazil, Canada, Cook Islands, Cote d'Ivoire, Croatia, Egypt, France, Kenya, Kiribati, Liberia, Malaysia, Maldives, Marshall Islands, Mexico, Netherlands, Nigeria, Norway, Republic of Korea, Saint Kitts and Nevis, Sierra Leone, South Africa, Spain, Sweden, Syrian Arab Republic, and Tuvalu) have ratified the Convention, representing only 25.32% of world merchant shipping tonnage (IMO 2011). While the U.S. played a large part in setting the BWM Convention standards, they have yet to ratify the Convention.

4.3.2: International Hull

Similar to Washington, there are currently no international regulations related to controlling the spread of AIS via hull fouling, but there are regulations related to anti-fouling paints. The International Maritime Organization International Convention on the Control of Harmful Anti-fouling Systems on Ships was adopted October 5, 2001 and entered into force on September 17th, 2008. The Convention states that parties to the convention are required to prohibit and/or restrict the use of harmful anti-fouling systems on ships flying their flag, as well as ships not entitled to fly their flag but operate under their authority and all ships that enter a port, shipyard or offshore terminal of the signed party. The Convention also states that all ships shall not apply or reapply organotin compounds which act as biocides, and

by the effective date of the Convention ships either shall not bear such compounds on their hulls or shall bear a coating that forms a barrier preventing compound leaching.

As of January 28, 2011 47 countries (Antigua and Barbuda, Bahamas, Belgium, Bulgaria, Canada, Cook Islands, Cote d'Ivoire, Cyprus, Denmark, Estonia, Ethiopia, Finland, France, Germany, Greece, Hungary, Iceland, Japan, Jordan, Kiribati, Latvia, Lebanon, Liberia, Lithuania, Luxembourg, Malaysia, Malta, Marshall Islands, Mexico, Morocco, Netherlands, Nigeria, Panama, Poland, Republic of Korea, Republic of Moldova, Saint Kitts and Nevis, Serbia, Sierra Leone, Singapore, Slovenia, Spain, Sweden, Syrian Arab Republic, Tuvalu, United Kingdom, and Vanuatu) have signed the IMO Convention on the Control of Harmful Anti-Fouling Systems on Ships, representing 75.29% of the world's shipping tonnage. (IMO 2011). The United States has not ratified this convention and does not abide by the requirements.

5. Bi-State Analysis of Current Practices and Regulations

Climate differences, as described in the section on state regulations, often indicate that aquatic invasive species would not be able to thrive in both Washington and Hawaii. However, a lack of consistent policies and regulations in Washington and Hawaii has directly resulted in overlapping AIS concerns.

One direct example of the AIS connection between Washington and Hawaii is the recorded introduction of the blue mussel, also known as the Mediterranean mussel (*Mytilus galloprovincialis*). Blue mussels were observed on the hull of the U.S.S. Missouri, which was towed to Pearl Harbor, Oahu, Hawaii from Puget Sound

Naval Shipyard in Bremerton, Washington. Blue mussels, considered AIS in Hawaii and Washington, were observed spawning on their arrival in Honolulu, and juveniles were observed and identified three months later (Godwin, Eldredge, & Gaut 5).

Other examples of AIS that have been established in both Washington and Hawaii through either ballast or hull fouling are *Sargassum muticum*, *Schizoporella errata*, and *Schizoporella unicornis*. *Sargassum muticum*, commonly referred to as Sargassum, is a large brown seaweed. It grows attached to rocks, with a maximum of 5 cm holdfast, and an additional 5 cm of height. These are the maximum growth specs for Washington State, however, in warmer waters off the coast of Hawaii it has been known to grow to up to 12 meters in length. Sargassum has negative impacts both economically and environmentally, and can clog waterways, preventing marine transit and recreational activities. It can also clog intake pipes, as well as choke out local species. *Schizoporella errata* and *Schizoporella unicornis* are fouling bryozoans, and are of concern in both Washington and Hawaii as they out-compete natives for space and food (Global Invasive Species Database).

Washington and Hawaii have also identified their environment as susceptible to the establishment of *Carcinus maenas*, commonly known as the European green crab. Neither states have established populations, but individuals of the species have been found in both states. Hawaii and Washington have voiced concern over the likely arrival and establishment of the species (Global Invasive Species Database).

Co-establishment of the above AIS, as well as the establishment of hundreds of others within both Washington and Hawaii clearly illustrates the need for

improved policies, regulations, and practices within both states. Hawaii and Washington policies regarding ballast and hull fouling have several similarities, yet also have key differences.

Ballast water regulation similarities include the stringent reporting requirements, mandatory ballast water management plans on board all vessels which enter state waters, the requirement for open-ocean ballast water exchange outside of the exclusive economic zone of the state, and the resulting fines associated with violating any of the above requirements. Although reporting requirements are nearly identical, Washington and Hawaii compliance rates vary greatly. According to Third Biennial Report of the National Ballast Information Clearinghouse, compiled by the Smithsonian Environmental Research Center, the most recent compliance data (2004-2005) indicates an 88.6% compliance rate on the West Coast (Washington, Oregon, and California), versus 76.1% compliance rate in Hawaii. Compliance on the West Coast increased 19.0% during 2004-2005, while there was a 15.4% decrease in compliance in Hawaii. Hawaii was the only area of the United States showing a decrease in ballast water reporting compliance (Smithsonian 5). Key differences between Washington and Hawaii relate to a lack of details within Hawaiian policy. This lack of detail may have a connection to the lack of compliance as recorded by the Smithsonian.

5.1: Ballast

Current ballast water practices, ranging from treatment to regulations, have several key problems. First, utilizing ballast water exchange as the currently

suggested method for reducing AIS has several drawbacks. The ability of a vessel to effectively remove and exchange all of its ballast is variable depending on the specific vessel (National Research Council 25). In the most efficient vessels it is still near impossible to remove all sediments and water from the bottom of the ballast tank, which results in remaining organisms. A vessel considered free of ballast typically contains 150 tons of residual water and mud, due to the fact that the nozzle which pumps water from each tank hangs several feet above the tank floor (Harder 235). Exchange also does not remove organisms stuck to the sides or supports within the tank (Baskin 734).

According to McCollin, Shanks, and Dunn, even though ballast water exchange creates an overall reduction in number and abundance of taxa found on board, this reduction was not consistent between tanks and voyages. This same research also showed that even with a reduction in number of species found in water, there were also several incidences of an increase in potentially harmful species (536). Also, safety concerns arise when the vessel has to flush its ballast water mid-transit. Ballast's purpose is to help stabilize the ship during transit, and the removal of this stability creates a window of increased danger due to capsize (Gramling 22). At this point, most regulations allow for ballast water exchange to be bypassed if the vessel captain feels conducting the exchange would be dangerous for the vessel or any crew on board. No secondary opinions on safety are required, and no explanation other than reporting that exchange was bypassed for safety is necessary (Endresen 615). The issue of shipping patterns also raises concern. A

large proportion of vessel trips do not cross the necessary depth and off shore distance for effective exchange (Endresen 618).

The current mechanisms of regulation also have several problems. Current regulations create a confusing, overlapping, and possibly conflicting reporting situation, which is problematic for the shipping industry (U.S Coast Guard 2006, 5). Having state regulations that differ from federal regulations and proposed international regulations makes compliance exceptionally difficult. The current voluntary status of ballast water management has resulted in low compliance rates. According to the National Ballast Information Clearinghouse, compliance to voluntary reporting was only 30.4% during the first 24 months that reporting requirements were in effect. About one half (51.2%) of the reporting ships that discharged ballast water performed some degree of ballast water exchange (U.S. Coast Guard 2001). According to existing U.S. regulations, exchange is not suggested, even on a voluntary basis, if a vessel does not travel outside of the U.S. EEZs, or Exclusive Economic Zones (NISA). This is problematic due to the fact that travel from port to port within the U.S. has the potential of spreading AIS. Travel between San Francisco Bay, which is heavily impacted by AIS, to the Puget Sound, which is only moderately impacted by AIS, has the potential of environmental and economic harm for the Puget Sound area.

Also, a lack of discharge standards has created a situation of standstill in the development and implementation of new ballast water treatment technologies. In order to obtain greater environmental benefits, state of the art ballast water treatment technology needs to be widely available and affordable, however,

manufacturers are unwilling to take the business risks necessary to begin commercially producing treatment systems unless they know the discharge standards those systems need to meet (U.S Coast Guard 2006, 6).

All vessels of the United States' Armed Forces are exempt from ballast regulations in Washington and Hawaii. This does not mean military vessels are not conducting ballast water exchanges or following the suggested guidelines, it just means they are exempt from reporting, resulting in a lack of knowledge in this area.

5.2: Hullfouling

Hull fouling regulation issues are hard to identify due to the fact that there is currently little to no regulation relating to hull fouling and the transmission of aquatic invasive species. Inconsistent regulations and rules regarding ablative paints, anti-fouling systems, and boat cleaning, as mentioned previously, create a confusing atmosphere for both private and commercial vessel operators. Lack of reliable scientific data regarding AIS and hull fouling is also an issue.

The above mentioned military exemption is particularly pertinent to Washington and Hawaiian policies due to the heavy military presence in both states. It is reasonable to expect that this exemption will remain in place for hull fouling regulations as well as the already written ballast water regulations. The only documented direct transmission of invasive species from Washington to Hawaii was the previously mentioned blue mussel, transferred via hull fouling from Puget Sound Naval Shipyard in Bremerton, WA to Pearl Harbor in Honolulu, HI.

6. Suggested Improvements

The key to reducing and preventing AIS transmission through the vectors of ballast and hull fouling is creating a consistent set of policies, therefore creating a maritime shipping environment that is easy to comply with. Moving towards consistency will be key to success. To move towards this goal, the following recommendations are suggested.

Hawaii and Washington could improve in both the ballast and hull fouling segments of maritime transportation, however, the hull fouling component is a more prominent issue at this point in time. The complete lack of regulations regarding AIS transportation via hull fouling is detrimental to both states' economic and environmental situations.

In order to improve the ability to regulate hull fouling issues, it strongly suggested that the legislatures from both Hawaii and Washington pressure the United States to sign on to the IMO International Convention on the Control of Harmful Anti-fouling Systems on Ships. Creating a national standard for the use of ablative paints and regulating the anti-fouling technologies available will create a base that will allow for long term AIS management policies and goals. Without consistent standards relating to ablative paints and anti-fouling mechanisms, it is difficult to set realistic policies.

In addition to the issues with ablative paints, it is also important to focus regulations on activities that can reduce initial AIS transmission. Emphasis should be placed on preventative techniques. The first suggested preventative technique is to restrict time in port to essential operations only, such as cargo operations, fueling,

and loading supplies. For vessels that intend longer term stays, such as cargo barges, crane barges, drilling platforms, floating drydocks, and decommissioned military and personal vessels, it is suggested for states to develop quarantine procedures for vessels prior to docking, or to require a mandatory out of water cleaning prior to permanent or long term docking.

Hawaii and Washington could improve ballast policies by passing legislation that is consistent with International Maritime standards. The IMO Ballast Water Convention represents 10 years of consensus building and provides a detailed and realistic plan of action to battle AIS. The United States has been involved in setting the regulations proposed by the IMO, but has not ratified the convention. Hawaii and Washington choosing to pass state standards consistent with the IMO would be an indicator to national level government that ratifying the convention is desired. The BWM Convention will not go into effect until it has 30 signatories, representing 35% of world shipping tonnage. World shipping tonnage is a measure of total volume of ships operating worldwide, irrespective of actual cargo carried. If the U.S. were to ratify the convention, this would represent approximately 15% of world shipping tonnage (IMO 2011), and would be enough to put the IMO Convention into action. Ratification of the BWM convention is supported by several key organizations involved in shipping, including the Coast Guard, American Association of Port Authorities, the Shipping Industry Ballast Water Coalition (which includes representative from several major shipping corporations), and several other industry related groups (American Association of Port Authorities, Coast Guard 2002, Coast Guard 2004, Coast Guard 2005, Shipping Industry Ballast Water Coalition).

Adopting a ballast water treatment standard at a state level, preferably by adopting a treatment standard consistent with the IMO, would help encourage design and implementation of new ballast water treatments. Allowing for adjustments to the standard based upon available technologies is also important. The battle over which should come first, the treatment standard or the preferred treatment technique needs to be resolved. Waiting for treatment techniques to be developed has been slow, for reasons discussed earlier, and may be expedited with the phased implementation of treatment standards. It is also important that any standards set be required for any travel, even if within the EEZs of each individual state or climate zone. Preventing transmission of AIS from port to port will be key in slowing down the spread of species.

Also important for both Washington and Hawaii is to require preventative measures in ballast water management plans. Both states currently require all vessels to have a ballast water management plan on board, but do not have any requirements for what is found in the plan. Emphasizing the need to reduce initial AIS intake in ballast will allow for less burden to be placed up treatment technologies or exchange. Such preventative measures include: minimizing ballasting in ports and coastal areas, avoiding ballast intake at night, and avoiding ballast uptake in 'hot spots', or areas near sewage outfalls or have known AIS infestations (Globalballast 2008).

In order for these recommendations to become policy both states need to have increased funding dedicated to AIS. Both Hawaii and Washington have the information and potential for great improvements in policy and enforcement,

however, neither can do so without increased funding. This funding could be used for education and outreach, creating a more communicative environment between marine vessel operators and managers and those working to reduce AIS introductions. Funding could also be used to increase vessel inspections, helping to close an information gap that forms from a self-reporting system.

7. Conclusion:

Aquatic invasive species and the related dispersal by marine transportation is a global and ongoing problem. The lack of comprehensive and collaborative policy has resulted in a regulatory situation that is confusing and difficult to navigate for both private and commercial vessel owners and operators. Improvements to the policy and regulatory environment could result in increased effectiveness when battling aquatic invasive species. The comparison of Hawaii and Washington identifies a number of policy constraints and possibilities to ensure ecological and economic viability.

Hawaii and Washington could both make individual or joint policy improvements, as listed above, that would result in an increased line of defense against the transmission of aquatic invasive species. However, without efforts on a larger scale, individual and even joint state changes are not going to result in a drastic reduction in invasive species transmissions and establishments. Creating consistent and thorough policies at a national and international level is going to be the necessary change in order to reduce AIS transmissions and the resulting economic and environmental impacts. Modeling state ballast policies to match

those of the International Maritime Organization works towards a consistent international policy framework, and also places pressure on the United States to move towards those standards at a national level. As there are no current best practices available for the prevention of AIS through hull fouling, it is suggested that Washington and Hawaii focus on creating consistent port based prevention efforts, allowing for initial protection while more research is completed and best practices can be established.

Works Cited

- American Association of Port Authorities. "Ballast Water Management. Legislative Priorities. 01 January 2011 www.aapa-ports.org
- "Anti-Fouling Bottom Paint." *Boat Paint and Marine Painting*. Web. 18 Jan. 2011. <www.marinepainting.net/anti-fouling-bottom-paint.html>.
- Bailey, Sarah A., Ian C. Duggan, Colin D.A. Overdijk, Philip T. Jenkins, and Hugh J. MacIsaac. "Viability of invertebrate diapausing eggs collected from residual ballast sediment. Limnology and Oceanography. 48.4 (2003): 1701-1710.
- Ballast Water Management. RCW 77.120. 30 June 2007.
- Ballast Water Management and Control- Reporting and sampling requirements. WAC 220-77-0900C.
- Baskin, Yvonne. "Curbing undesirable invaders." BioScience. 46.10 (1996): 732-736.
- Buck, Eugene H. "Ballast Water Management to Combat Invasive Species." CRS Report for Congress. (2005).
- Cangelosi, Allegra A., Nicole L. Mays, Mary D. Balcer, Euan D. Reavie, Donald M. Reid, Rochelle Sturtevant, and Xueqing Gao. "The response of zooplankton and phytoplankton from the North American Great Lakes to filtration." Harmful Algae 6 (2007): 547-566.
- Carlton, James T., Donald M. Reid, and Henry van Leeuwen. "Shipping Study: The Role of Shipping in the Introduction of Non-indigenous Aquatic Organisms to the Coastal Waters of the United States (Other than the Great Lakes) and an analysis of control options." NTIS Report #AD-A294809 US Coast Guard Report # CG-D-11-95. (1995).
- Center for Coastal Resources. Marine bioinvasions fact sheet: ballast water treatment options. 2006. MIT Sea Grant. 20 January 2011 <<http://massbay.mit.edu/resources/pdf/ballast-treat.pdf>>
- Champ, Michael A. "Marine Testing Board for certification of ballast water treatment technologies." Marine Pollution Bulletin 44 (2002): 1327-1335.
- Coutts, A. D., K. M. Moore, and C. L. Hewitt. "Ships' Sea-chests: an Overlooked Transfer Mechanism for Non-indigenous Marine Species?" *Marine Pollution Bulletin* 46 (2003): 1504-515. Print.
- Dobroski, Nicole A. "Aquatic invasive species and ballast water management."

- Discharge of Polluting Matter in Waters Prohibited., § RCW 90.48.080 (1987).
Print. California State Land Commission.
- Eldredge, L. G., and J. T. Carlton. "Hawaiian Marine Bioinvasions: A Preliminary Assessment." *Pacific Science* 56 (2002): 211-12. Print.
- Endresen, Øyvind, Hanna Lee Behrens, Sigrid Brynstad, Aage Bjørn Andersen, and Rolf Skjong. "Challenges in global ballast water management." Marine Pollution Bulletin 48 (2004): 615–623.
- Fofonoff, P. W., G. M. Ruiz, B. Steves, and J. T. Carlton. "In Ships or on Ships? Mechanisms of Transfer and Invasion for Nonnative Species to the Coasts of North America." *Invasive Species* (2003): 152-82. Print.
- GloBallast. 10 Most Unwanted. 08 January 2011.
<http://globallast.imo.org/poster4_english.pdf>
- GloBallast. Ballast Water News. 16 (2004): 1-12.
- GloBallast. Stopping the ballast water stowaways. (2002).
- GloBallast. 2008. 23 December 2010 < <http://globallast.imo.org>>
- Godwin, L. S., L. G. Eldredge, and K. Gaut. *The Assessment of Hull Fouling as a Mechanism for the Introduction and Dispersal of Marine Alien Species in the Main Hawaiian Islands*. Bernice Pauahi Bishop Museum Hawaii Biological Survey- Bishop Museum Technical Report #28. Honolulu, HI, 2004. Print.
- Godwin, L. Scott. "Hull Fouling of Maritime Vessels as a Pathway for Marine Species Invasions to the Hawaiian Islands." Web. 5 Jan. 2011.
<www.nmri.go.jp/main/cooperation/ujnr/24ujnr_paper_us/Environmental_Science_and_Engineering/ESE_Godwin.pdf>.
- Godwin, L. Scott. *Marine Invasive Species Transported by Vessel Hull Fouling: Potential Management Approaches*. Hawaii Biological Survey. Bernice Pauahi Bishop Museum. Web. 12 Jan. 2011.
<www.pices.int/publications/presentations/pices_13/pices_13_s5/godwin_s5.pdf>.
- Gramling, Jessica. Ballast water and shipping patterns in the Puget Sound: Considerations for siting of alternative ballast water exchange zones. Olympia, WA: Puget Sound Water Quality Action Team, 2000.
- Harder, Ben. "Stemming the tide." Science News. 161.15 (2002): 234-236.

- Hawaii Administrative Rules, Title 13, Department of Land and Natural Resources, Subtitle 4, Fisheries, Part IV Fisheries Resource Management, Chapter 76, Non-Indigenous Aquatic Species (2007). Print.
- Hawaii. The Department of Land and Natural Resources. Division of Aquatic Resources. *State of Hawaii Aquatic Invasive Species Management Plan*. By Andrea D. Shluker. 2003. Print.
- "Hull Cleaning and Boat Washing | Clean Green Boating | Washington State Department of Ecology." *Washington State Department of Ecology | Home Page | ECY WA DOE*. Web. 20 Jan. 2011.
<<http://www.ecy.wa.gov/programs/wq/nonpoint/CleanBoating/hull.html>>
- Interim ballast water discharge standard approval process. WA 220-77-09500A.
- International Maritime Organization. 22 January 2011. < www.imo.org>
- International Marine Organization (IMO). *Focus on IMO: Anti-fouling Systems*. Rep. 2002. Print.
- International Maritime Organization*. 2008. International Convention on the Control of Harmful Anti-fouling Systems on Ships.
- Kaluza, Pablo, Andrea Kolzsch, Michael Gastner, and Bernard Blasius. "The Complex Network of Global Cargo Ship Movements." *Institute for Chemistry and Biology of the Marine Environment* (2010): 1-24.
- Library of Congress. Thomas Website. < <http://thomas.loc.gov>>
- Lewis, J. *Hull Fouling as a Vector for the Translocation of Marine Organisms, Phase 3: The Significance of the Prospective Ban on Tributyltin Antifouling Paints on the Introduction and Translocation of Marine Pests in Australia*. Report to the Department of Agriculture, Fisheries, and Forestry- Australia. Report No. 2. Print.
- McCollin, Tracy, Aileen M. Shanks, and John Dunn. "The efficiency of regional ballast water exchange: Changes in phytoplankton abundance and diversity." *Harmful Algae* 6 (2007) 531–546.
- Meyerson, Laura A., and Harold A. Mooney. "Invasive Alien Species in an Era of Globalization." *Frontiers in Ecology and the Environment* 5.4 (2007): 199-208.
- Michin, D., and S. Gollasch. "Fouling and Ship's Hulls: How Changing Circumstances and Spawning Events May Result in the Spread of Exotic Species." *Biofouling* 19 (2003): 111-22. Print.

- National Ballast Information Clearinghouse (NBIC). Smithsonian Environmental Research Center. 05 January 2011 <<http://invasions.si.edu/nbic/>>
- National Invasive Species Act. Pub. Law 104-332. 14 November 1996.
- National Oceanic and Atmospheric Association (NOAA). *National Oceanographic Data Center*. 05 January 2011. <www.noaa.gov>
- National Research Council. Stemming the tide: controlling introductions of nonindigenous species by ships' ballast water. Washington, D.C.: National Academy Press, 1996.
- Nehring, S. "After the TBT Era: Alternative Anti-fouling Paints and Their Ecological Risks." *Senckenbergiana Maritima* 31.2 (2001): 341-51. Print.
- Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990. USC 4701. 29 December 1990.
- Prince William Sound Regional Citizens' Advisory Council. Ballast water treatment methods- fact sheets. 2005. 8 January 2011 <<http://www.pwsrccac.org/resources/reportsavail.html>>
- Puget Sound Action Team. Ballast Water Management in Washington State: a report to the State Ballast Water Work Group to the 2007 Regular Session of the Washington State Legislature. March 2007.
- Railkin, A. I. *Marine Biofouling: Colonization Processes and Defenses*. Washington, DC: CRC, 2004. Print.
- Savarese, Jason. "Preventing and Managing Hull Fouling: International, Federal, and State Laws and Policies." Proc. of 14th Biennial Coastal Zone Conference, New Orleans, Louisiana. Print.
- Shipping Industry Ballast Water Coalition. Letter in response to docket no. USCG-2001-8737—Potential Approaches to Setting Ballast Water Treatment Standards. 29 June 2001.
- Showalter, Stephanie, and Jason Savarese. *The Existing U.S. Legal Regime to Prevent the Hull Transport of Aquatic Invasive Species*. White Paper Prepared for the California Sea Grant Law Center. 2005. Print.
- Smithsonian Environmental Research Center. "Invasive Species." 7 January 2011. <www.serc.si.edu/watershed/may2001/invasivespecies.htm>
- Smithsonian Environmental Research Center. "Marine Invasions Research Lab: Hull Fouling." 21 January 2011. <www.serc.si.edu/labs/marine_invasions/vector_ecology/fouling.aspx>

Takata, L., M. Falkner, and S. Gilmore. *California State Lands Commission Report on Commercial Vessel Fouling in California: Analysis, Evaluation, and Recommendations to Reduce Nonindigenous Species Release from the Non-Ballast Water Vector*. Report to the California State Legislature. Print.

Tang, Zhijian, Michael A. Butkus, and Yuefeng F. Xie. "Crumb rubber Filtration: A potential technology for ballast water treatment." Marine Environmental Research 61 (2006): 410–423.

United States Coast Guard. Report to Congress on the Voluntary National Guidelines for Ballast Water Management. November 2001.

United States Coast Guard. Testimony of Richard Steinke, Executive Director, Port of Long Beach, Chairman, American Association of Port Authorities, before a Joint Hearing of the House Transportation and Infrastructure Subcommittees on Coast Guard and Maritime Transportation and Water Resources and the Environment. 15 May 2002.

United States Coast Guard. Testimony of Joseph J. Cox on behalf of the Shipping Industry Ballast Water Coalition regarding "Ballast Water Management: New International Standards and National Invasive Species Act Reauthorization" before the Coast Guard and Maritime Transportation and Water Resources and Environment Subcommittees of the House Transportation and Infrastructure Committee. 25 March 2004.

United States Coast Guard. Testimony of Donald L. O'Hare Vice President of the World Shipping Council on Reduction of Air Pollution from Ships and Ballast Water Management before the Subcommittee on Coast Guard and Maritime Transportation of the House Committee on Transportation and Infrastructure. 11 July 2006.

United States Department of Homeland Security and United States Coast Guard. Statements of Rear Admiral Thomas Gilmour on Ballast Water Management and the Ballast Water Management Act of 2005, S. 363 before the subcommittee on Committee on Commerce, Science, and Transportation, U.S. Senate. 15 June 2005.

Washington Department of Fish and Wildlife. Washington State Ballast Water Program. 10 January 2011. <<http://wdfw.wa.gov/fish/ballast/ballast.htm>>