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# Elements of a Successful Plan: Marine Invasive Species Management

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# Elements of a Successful Plan: Marine Invasive Species Management

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Capstone requirement of the Community  
Planning & Development program –  
Professor Yuseung Kim - advisor

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## Definition of Terms

**Aquatic Invasive Species (AIS):** Plant or animals that live the majority of their life cycle in a fresh or salt water environment.

**Ballast Water (BW):** Ballast water is typically used by large cargo vessels that take long voyages across oceans between countries. To keep the ship more stable, large tanks are filled with up to millions of gallons of water at the start of the journey. The water is then dumped at the end. It is estimated that roughly 3,000 alien species are transported by ballast water each day (although not all survive) (Smith D. L., 2006).

**Bio fouling:** *“The gradual accumulation of waterborne organisms (as bacteria and protozoa) on the surfaces of engineering structures in water that contributes to corrosion of the structures and to a decrease in the efficiency of moving parts”* – Merriam-Webster Dictionary

**Eradication:** *“The removal of every potentially reproducing individual of a species or the reduction of their population density below sustainable levels”* - (Myers, Simberloff, Kuris, & Carey, 2000).

**Hull Fouling:** Marine organisms fasten themselves to the bottoms (hulls) of ships. They can then "hitch a ride" on the hull from one port to another, occasionally invading the new port if conditions are right. This leads to marine invasive species introductions (Smithsonian Environmental Research Center, 2004)

**Invasive Species:** *“Non-native 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”* – (Nonindigenous Aquatic Nuisance Prevention Control Act, 1990)

**Marine Invasive Species:** A plant or animal that lives the majority of its life in a marine or salt water environment.

## **Introduction:**

*Problem* –Marine invasive species are becoming an increasing threat to marine ecosystems and coastal economies around the world.

*Question* –What have communities/towns/states/regions/countries done to prevent introduction and to control and eradicate marine invasive species? What can Maine learn from other aquatic invasive species programs to control and prevent marine invasive species spread in the future?

*Purpose* – The purpose of this study is to determine the elements of an effective invasive species program in a variety of places and to come up with suggestions for how to implement this in Maine, specifically in terms of combatting Green Crabs.

## **Invasive Species and Worldwide Efforts**

Today's expansive transportation network allows for the rapid spread of non-native species. As a result, there has been a significant increase in the introduction of non-native species to new areas. These introductions can cause the destabilization of ecosystems which can lead to a loss of ecosystem services, functions and resources (Locke & Hanson, Rapid Response to Non-Indigenous Species, 1. Goals and History of Rapid Response in the Marine Environment., 2009). While invasive species are any flora or fauna that is not native in a region and has negative effects on economy, environment or health, not all introduced species are invasive. Introduced species that do not have a negative effect on the economy, environment or health are non-native and do not require the same amount of management. This report will focus on marine invasive animals but will touch on aquatic invasive species because fresh, estuarine and marine efforts are often combined in aquatic invasive species management plans.

Marine invasive species are difficult to manage because they are not well understood and their vectors of dispersal are complex and widespread. Also, once established, they are especially difficult (and sometimes impossible) to eradicate and control which is why stopping introduction is the first and foremost goals of most management plans. Introduced species that are slow to disperse/reproduce and introductions that are contained in small areas are the easiest to eradicate/control but still often require large effort. Quickly dispersing species with a planktonic larval stage of reproduction are very difficult to contain. However, there are methods of control that can be effective. Using green crabs as an example, some ways to control populations include: trapping, chemical control, biological control and genetic control (Kern, 2002).

There are numerous international efforts to combat the introduction of invasive species. The International Maritime Organization (IMO) is one that has worked to develop policies and guidelines regulating international trade and commerce in an attempt to limit the spread of invasive species. The IMO developed a set of international guidelines for ballast water control in 1993 that has been used as a model for ballast water management. The Global Invasive Species Program was established in 1997 to address the invasive species problem and to provide support to the implementation of Article 8(h) of the Convention on Biological Diversity. The goal of this Convention is to coordinate existing efforts and promote information exchange. However, the United States has not become a Party to the convention (Hewitt, Everett, & Parker, 2009; Connecticut Aquatic Nuisance Species Working Group, 2006). The International Council for the Exploration of the Seas is another organization that conducts research on various aspects of the spread of aquatic invasive species. No international entity specifically includes and addresses biofouling and the use of non-native species for establishing new aquaculture industries or fisheries, both of which led to the spread of invasives (Hewitt, Everett, & Parker, 2009).

Despite real international efforts (most of which are voluntary), much more work is needed to control marine invasive species. This report will analyze different approaches to managing aquatic invasive species in a variety of places around the world and the US. Through comparison of the success or lack thereof of these efforts, this report will also look at the elements of successful aquatic invasive species management. The final section of this report will use lessons learned from study sites to make suggestions as to how to improve Maine's marine invasive species efforts and will take a closer look at Maine's marine invasive species problem through analysis of the example of the European Green Crab (*Carcinus maenas*).

### **Spread of Invasive Species – Vectors**

A number of inter- and intra-country pathways or vectors for spread of marine invasive species have been identified. It is universally accepted that the best way to control the spread of invasives is to stop their initial introduction and this can only be achieved through managing dispersal vectors. There are numerous vectors that must be considered. The first is natural dispersal and introduction which occurs passively through wind and currents and actively in mobile species. Because ocean water temperatures are warming, organisms are able to survive in places that they couldn't previously tolerate, leading to new invasions. Other vectors to be considered are aquatic resources such as water diversions and fish ways. Furthermore,

transportation is one of the most common mechanisms for aquatic invasive species introduction and dispersal. Boats (commercial and recreational) are a common example of a transportation vector that has been known to spread marine invasive species. Invasive organisms grow off of or attach onto boat hulls or equipment and are transported in this manner. Ballast water is the number one dispersal method of invasive species. Sea planes also spread alien organisms. Dredging equipment, construction equipment and dive and snorkeling gear are another way that aquatic invasive species have been known to spread. The final dispersal and introduction mechanism is organism handlers such as bait trade/anglers, aquaculture and seafood industry/retailers/restaurants/consumers. Aquarium industry/hobbyists, garden industry/gardeners, research facilities, stocking programs and bio-control programs are other examples of organism handlers that have the potential to spread marine invasive species (Connecticut Aquatic Nuisance Species Working Group, 2006). It is essential that management efforts consider and focus on these transport vectors if they wish to successfully control dispersal and introduction of marine invasive species.

### **US Federal Aquatic Invasive Species Policies**

The US Federal Government has recognized that dumping billions of gallons of water weekly into US harbors from every major port in the world is lending to the spread of marine invasive species. Federal marine invasive species policies have been created as a result. Multiple federal agencies work to combat invasive species but efforts could be expanded to limit introductions from international/interstate trade. The first major act passed by the federal government was in response to the negative economic and ecological effects of the introduction of the zebra mussel in 1990. The Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990 was created to encourage states to develop Aquatic Nuisance Species Management Plans. It was also created with the following objectives:

1. To prevent further unintended aquatic invasive species introductions.
2. To coordinate control efforts and federally funded research.
3. To develop and carry out environmentally sound control methods to prevent, monitor, and control introductions.
4. To understand and minimize damage to ecosystems.
5. To establish a research program and technology to assist states.

This act established the Federal Interagency Aquatic Nuisance Species Task Force which coordinates federal aquatic nuisance species management efforts with the efforts of the private sector and other North American interests. The panel works to achieve the previously stated objectives and operates through regional panels and species-specific working groups (Connecticut Aquatic Nuisance Species Working Group, 2006).

Ballast management regulations were also created as part of NANPCA. In 1996, ballast water guidelines were established for all US waters and were delegated to and completed by the U.S. Coast Guard. Additional voluntary National Guidelines were developed and implemented in 1999 and were applied to waters outside of the Great Lakes Ecosystem. This program consists of a list of comprehensive guidelines that includes requiring all vessels entering US waters to complete a Ballast Water Management (BWM) report. This became mandatory in 2004. All BWM reports are kept at the National Ballast Information Clearing House and there are fines for non-compliance. Unfortunately these guidelines are not consistently enforced, limiting effectiveness. These guidelines regulate where ballast operations can take place, cleaning and maintenance protocols and vessel-specific BW management plans. Additionally, all vessels transitioning to U.S. waters with ballast water taken on within 200 nautical miles of any coast must exchange BW mid-water prior to entering U.S. waters. They must also retain the BW on board while in the U.S. or use a USCG-approved alternative method for treating BW (such treatment options don't currently exist) (United States Coast Guard - Environmental, 2014).

Federal programs that exist outside of NANPCA mostly deal with transport and protection of valuable horticultural, aquaculture or endangered species. These laws include the Lacey Act of 1900, the Federal Seed Act of 1939, the Endangered Species Act of 1973, the Plant Protection Act of 2000, the Animal Health Protection Act and most recently, the Executive Order 13112 of February 1999 which established the National Invasive Species Council. This Council is charged with the biennial development of a National Invasive Species Management Plan (Connecticut Aquatic Nuisance Species Working Group, 2006).

Government Agencies that have made management and control of invasive species a priority are the Aquatic Nuisance Species Task force, the U.S. Department of Agriculture, the U.S. Army Corps of Engineers, the U.S. Coast Guard, National Ballast Water Information Clearing House, the U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, U.S. Geological Survey, National Oceanic and atmospheric Administration (Connecticut Aquatic



Nuisance Species Working Group, 2006). Although many Government Agencies work to help limit the spread and introduction of invasive species, the effort falls short.

### Overview of Marine Invasive Species in Maine

Some estimate that at least 64 non-native species have invaded the Gulf of Maine (Pappal, Marine Invasive Species: State of the Gulf of Maine Report, 2010). While many non-native species such as periwinkles, *Littorina littorea*, live in Maine waters, invasive critters exist as well. Green crabs, a variety of tunicates and skeleton shrimp, *Caprella mutica*, are few examples of marine invasive animals that can be found in the ocean off of Maine. Most management approaches have been voluntary and often sparse and inconsistent in Maine. In the Gulf of Maine, the only major regulation in place to prevent the spread of marine invasive species is ballast water policy under the National Invasive Species Act and the Canada Shipping Act. Most of the working elements of a successful rapid response and marine invasive species prevention plan do not exist. Maine is part of the Northeast Aquatic Nuisance Species Panel and it is the major regional coordinating body that manages invasive species. The Aquatic Invasive Species Management plan states that the Maine Department of Inland Fisheries and Wildlife (MDIFW) is the state agency leading efforts in Maine. Interestingly, there is no obvious information on their website about invasive species. The Department of Marine Resources is listed as filling this role in other publications (Hart, 2006). The Department of Conservation works with the MDIFW when response efforts involve state facilities or surface use restrictions. The Marine Monitoring and Information Collaborative is the only consistent monitoring program in the Northeast and it only has a few monitoring sites in Southern Maine (the MDIFW also receive reports). There are much more comprehensive monitoring programs in place for freshwater invasive plants in Maine than for marine invasives. Maine does have a rapid response plan in place but it is focused mostly on freshwater plants. There have been no known organized marine invasive species rapid response actions using the plan. The part of the rapid response plan that focuses on aquatic animals, focuses on freshwater fish although it states “*it does not preclude the department from using the same kind of procedures to respond quickly to other faunal infestations such as zebra mussels*” (Dominie Consulting, 2006). The few parts of the plan that could conceivably cross over to marine invasive animals do not hold any regulatory authority (Pappal, Marine Invasive Species: State of the Gulf of Maine Report, 2010). It is clear

that Maine has a long way to go if it hopes to quickly and effectively respond to marine invasive species.

### **Overview of Study and the European Green Crab**

European green crabs are not the most recently introduced marine invasive species to Maine waters but they are arguably the most detrimental to its marine ecosystems and the coastal economy. There are a number of questions surrounding the recent explosion in numbers of the invasive green crabs. The main focus of this project is based on the question: what are current efforts to study and combat marine invasive species in this area, this state and worldwide and how can we better eradicate and control marine invasive species today and in the future (using green crabs as a specific example)?

Like many marine invasive species, European green crabs likely arrived in the Northeastern United States via ballast water or shipping. It is estimated that they were first introduced in the late 1800s. The European Green crab is a surmounting threat to waters in the Pacific US and as well as the Gulf of Maine. As mentioned previously, some non-native species exist without incurring large impacts on ecosystems and coastal economies but green crabs are quickly wreaking havoc on ecosystems of intertidal zones up and down the coast and more recently in deeper waters.

Clam diggers and scientists alike theorize that the increase in green crab numbers has led to increased predation of softshell clams (*Mya arenaria*) and decimation of eelgrass (*Zostera marina*) beds. Their effects on marshes, other intertidal species and lobster are yet to be quantified but could be significant in the near future. There was a similar spike in numbers of this crab in the 1950s (which is around the time that they were first seen in maritime Canada) due to several warmer than average years, but subsequent cold winters killed most of the expanding population. Green crab numbers are on the rise again but this time scientists worry that thanks to climate change, we won't see a series of winters cold enough to control the population any time soon; and temperature is the only know control of green crab populations. Additionally, scientists are researching the possibility that green crabs of a genetic variation that can withstand colder temperatures may be supplementing the expanding population (Pappal, Marine Invasive Species: State of the Gulf of Maine Report, 2010). An additional concern is that if green crab numbers continue to rise and all bivalves are consumed, juvenile lobsters will be next, threatening Maine's thriving lobster fishery.

One of the most troubling results of the explosion of the green crab population is how sudden and unexpected it has been. Numerous marine labs, scientists, clammers and citizens are working to learn more about this invasive critter in a reactionary attempt to stifle the population's growth. The most popular ideas surround the creation of a market for green crabs as fish food, lobster bait, compost or human food and to put up fences to keep them away from eelgrass beds and clam flats. However, there is more work that could be done concerning this recent invasion. Learning how other places have planned for and prevented marine invasions could be useful in combating the problem and the inevitable future invasions in the Gulf of Maine. This report will examine and outline some of the work and studies that are currently being undertaken in Maine to assess information and effort gaps. It will then explore what the 14 study locations have done to eradicate and prevent marine invasives. The comparative analysis will help determine common characteristics of their management efforts. This study will look at current management efforts in Maine as well as what is missing that could be learned from the study locations to strengthen Maine's war on marine invasive species.

### **Current European Green Crab Control and Research Efforts**

In response to the before mentioned invasive European green crab population explosion, green crabs have become a hot topic in Maine and many reactionary responses are in progress. Below is a table of many of the known efforts in Maine.

**Table 1. Current and recent green crab control or research efforts underway in Maine as of April 2014.**

<b>Project</b>	<b>Project Type</b>	<b>Project Description</b>	<b>Project Contact</b>
<b>Clam bed fencing</b>	Research, Clam protection	Money was allotted by the Town of Freeport to conduct a study that involved putting fences up around known productive areas of clam flats in an attempt to keep green crabs out.	Freeport, Project Coordinator: Dr. Brian Beal (Joseph, 2013).
<b>Clam flat netting</b>	Research	Eight 12-foot x 20-foot nets were used to protect established clams and newly settled clam spat from green crabs. Plots were sampled for clams at the end of the season.	Penobscot; Freeport, Project Coordinator: Dr. Brian Beal (Joseph, 2013).
<b>Clam pots and monitoring</b>	Research/ Education	In a study involving clam spat planted in the mud in garden pots, covered with netting, in an attempt to keep out green crabs, survival of clam spat is being studied. School children are involved in this on-going study, making it an	Project Coordinator: Dr. Brian Beal, Wells Estuary Reserve, Casco Bay Estuary

		educational program as well.	Partnership (Bayley-Smith, 2014)
<b>Eelgrass bed fencing</b>	Research	In Maquoit Bay, eelgrass transplants were put inside fences in historical eelgrass bed sites and eelgrass survival, growth and environmental conditions were observed.	Hilary Neckles, USGS (Neckles, 2013)
<b>Abundance survey</b>	Research	Volunteers from 30 municipalities conducted a rapid assessment of green crab populations across the state over a two day time period.	DMR, Dr. Brian Beal (Department of Marine Resources, 2013).
<b>Trapping</b>	Population Eradication/ Control	This project used 160 crab traps to trap and remove green crabs from active harvest locations in Freeport's waters. Green crab catch was recorded as part of the project.	Freeport, Project Coordinator: Dr. Brian Beal (Joseph, 2013).
<b>Green crabs as mince or paste added-value food product</b>	Population Control	A scientist at the University of Maine, Orono has been studying ways to make green crabs into an edible food mince or paste.	UMO (University of Maine, Orono, 2013)
<b>Green crabs as export for human consumption</b>	Population Control	A Canadian businessman has come to Maine claiming to have discovered a market for green crabs overseas. No crabs have been shipped overseas at this time.	Ron Howse, Tidalwater Seafood Co., Fredericton, New Brunswick (Bell, 2014; Brogan, 2014).
<b>Green crabs as compost</b>	Population Control	Some compost firms will take green crabs but at the time of this report there was no market for this particular use of green crabs.	(Trotter, 2013)
<b>Green crabs as aquaculture feed</b>	Population Control	Individuals in Maine are researching a potential market for green crabs as aquafeed.	John der Kinderen (der Kinderen, 2014; Maclean, 2013)
<b>Maine State Green Crab Task Force</b>	Political	In February, 2014, Governor LePage appointed a 12 person task force to focus on the green crab problem in Maine. However, the task force will dissolve in September 2014 and no money was assigned to this effort.	(Bennett, 2014)

Eradication is considered infeasible in areas with an already established population of green crabs (as is the case in Maine). However, prevention through anthropogenic transport vectors can be considered in places where green crabs or other marine invasives have not taken over. For example, the Australian Ballast Water Management Advisory Council has listed green

crabs as a target pest species and thus they are taking steps to limit the spread to uninfested areas by regulating ballast water (Klassen & Locke, 2007).

Some are attempting to control population numbers through creating markets for green crabs. For example, green crabs have been used as lobster, whelk and tautog bait and some have sold them on restaurant menus as specialty items (Deese & Arnold, 2014). Green crabs are consumed in their native region as a fried delicacy and as fish paste in Italy. Interestingly, green crabs have been overfished in their native range in Portugal (Klassen & Locke, 2007). However, green crabs are very difficult to process because the ratio of shell to meat content is high and when processed into a fish paste, biotoxins accumulate. Other attempts to monitor and control green crab populations have been attempted. For example, folks in Massachusetts have applied for funds from the Massachusetts Bay program to monitor green crab populations in the Great Marsh across Cape Ann and North Shore (Neidzinski, 2014). A project to remove green crabs in Kejimikujik National Park in PEI and has successfully controlled the green crab population in a relatively closed estuary by removing over one million green crabs (McCarthy, 2013). Other control method ideas include sound pulses, air exposure/desiccation, chemical and biological control, altered fishery practices and parasitic castrators. However, many of these options have not been tested due to expected unintended effects on surrounding environment and ecosystem (Walton, 2000). Numerous attempts to keep green crab numbers under control have shown that there is no easy answer.

## **Marine Invasive Policy Literature Review**

There is a consensus in the literature on the common dispersal mechanisms of non-native and invasive species. There is also agreement that range expansion and climate change are contributing to the increase in invasive species. It is commonly understood that introduction prevention is the best method of fighting invasives but there are mixed views on whether eradication and control are possible. In the United States government and state agencies have been slow to recognize and react to marine invasions, unlike terrestrial invasions of non-native species. This is partly due to a lack of solid information on impacts of invasive species on human health, ecosystem and economies (Hewitt, Everett, & Parker, 2009; Pappal, Marine Invasive Species: State of the Gulf of Maine Report, 2010). In some part, lack of effort and lack of literature focused on marine invasive species is a result of the fact that the impacts of these

invaders are not easily observed or understood as they take place underwater in a vast, open ecosystem and the focus of the threat is often broad. Chad Hewitt argues that the majority of demonstrable impacts are on ecosystem health and not on economic values (Hewitt, Everett, & Parker, 2009). However, other publications disagree and argue that economic impacts can be staggering (Pappal, Marine Invasive Species: State of the Gulf of Maine Report, 2010).

There are multiple publications that discuss individual, state and national aquatic invasive species management plans while few plans highlight and discuss plan priorities and few look at major policy and management gaps. Additionally, there are few studies that examine and analyze failed marine invasive species eradication efforts (Locke & Hanson, 2009). However, many authors agree that rapid response plans are a crucial second line of defense (after prevention) to combating marine invasive species, yet few states in the United States have these plans. A series of journal articles by Locke and Hanson analyze rapid response plans. They examine examples and management of successful control and eradication attempts. They also outline a framework for a comprehensive rapid response plan from the pre-invasion stage to post-invasion part of the process. However, they don't closely examine prevention (vector based dispersal) or risk assessment procedures as suggested by Lodge et al. (2006). Locke and Hanson examine Prince Edward Island and aspects of their current rapid response plan. There are numerous parts of the Maine Invasive Species Rapid Response Plan that do not concur with rapid response plan suggestions by other authors. For example, the Maine rapid response plan lists consulting the public early in the process but only "to the extent practical". This conflicts with Locke and Hanson's opinion that keeping stakeholders informed (at the very least) is crucial not only for eradication but also increased monitoring (Locke & Hanson, 2009). There is no known literature analyzing Maine's management plan and rapid response plan based on known effective management practices. Locke and Hanson as well as Lodge et al. suggest that funding is the major problem in combatting invasive species and most literature on attempted eradication efforts support this.

Many aquatic invasive species management plans, government websites and reports state that much is being done to combat invasives in their area. However, there is little evidence to support this. Many of the reports don't have any follow up requirements or evaluative measures in place to prove that the plans (when in use) are working. One report that examines this closely

in California is: *Managing Coastal Aquatic Invasive Species in California: Existing Policies and Policy Gaps* by Adrianna A. Muir, 2011. Although California's invasive species management plan boasts major progress, this report sheds light on the disjointed efforts using disparate authorities. It highlights the use of numerous laws and regulations that were not designed specifically for invasive species, therefore stating that they are all but ineffective. Chapter 19 in the book *Biological Invasions in Marine Ecosystems*, has an interesting take on this involving the U.S. as a whole. They state:

*“The broad mix of authorities and jurisdictions over the introduction and management of invasive aquatic species continues to complicate the development of a comprehensive and effective U.S. national regime. However, the coordinating activities of the ANSTF (Aquatic Nuisance Species Task Force) and the NICS (National Invasive Species Council) are resulting in significant improvements in coordination among agencies. Internationally, the U.S. has been a strong proponent of the IMO Ballast Water Management Convention, and continues to participate actively in the development of the numerous implementing guidelines”*. - (Hewitt, Everett, & Parker, 2009)

Although they agree that some of the work on aquatic invasive species is disjointed, they also argue that there have been significant improvements and shed a positive light on current efforts. However, this chapter doesn't support statements such as the one above with any solid examples (Hewitt, Everett, & Parker, 2009).

The report written by Muir closely examines the unsuccessful elements of the California aquatic invasive management plan. One example of this is the mention of inadequate authority for California to respond to invasions. This is the case in most states in the U.S., including Maine, but is not closely examined elsewhere. Locke and Hanson and Lodge et al. support this estimation. These authors also agree that surveillance, monitoring and education concerning marine invasive species are important but also often inadequate.

There are several known green-crab-specific invasive species management plans in place. The U.S., New Zealand and Australia are some examples of places that have chosen to create focused plans for green crabs. However, these publications differ significantly. The New Zealand Action plan is a brief educational document about green crabs with a very short section

on the actual plan of action. One action is amending the ballast water Import Health Standard by adding-high risk areas to the standard to reduce the risk of arrival of the crab. A second action involves increasing chances of detection by targeting green crabs in the national surveillance program and informing the public. The document is mostly geared toward educating the public (Ministry of Fisheries, 2001). This may be partly because green crabs have not yet invaded New Zealand. However, in Australia green crabs have not colonized all areas yet this country has an extensive, 44 page, national control plan. This plan includes a multi-year budget as well as a section called “A mechanism for monitoring of implementation of the National Control Plan and ongoing evaluation” (Aqual Pty Ltd, 2008). The U.S. national management plan for green crabs is similarly structured but it is unclear if it has ever been utilized as specific green crab efforts have varied greatly from place to place, especially between the east and west coasts. The U.S. national plan doesn’t tap into any state-specific networks of individuals in specific locations. The U.S. national plan has a budget in place through 2010 but has not been updated and does not have any on-going evaluative measures in place to reevaluate the plan, unlike the New Zealand Plan (Kern, 2002). In response to green crab invasion, Washington State created a specific green crab task force with support and funding from the governor and legislature (Washington Department of Fish and Wildlife, 2014). At this time Maine does not have a green crab specific management plan but a short-term task force was appointed by the Governor in February 2014. It is clear that management plans and actions vary significantly from place to place.

## **Methods**

Sites were selected for this study based on similarity to Maine and/or their location in green crab non-native established or potential range. The chosen study locations were: Massachusetts, Washington, South Carolina, Maine, Rhode Island, Connecticut, New York, New Jersey, Florida, California, Hawaii, New Zealand, Maritimes Canada and Australia (Appendix 2). States without Aquatic Invasive Species were not analyzed thoroughly except to determine if any marine invasive management attempts exist in the absence of a state plan. As expected, no such examples were found. Elements of the study location plans were investigated. Elements included in the table were selected based on authors suggestions in published literature and common plan elements (Locke & Hanson, Rapid Response to Non-Indigenous Species, 1. Goals



and History of Rapid Response in the Marine Environment., 2009). Elements analyzed include: presence of Aquatic Invasive Species Management Plan, public education campaign, ability to seize or destroy private property, presence of rapid response plan, federal/state/regional/town funding, regional cooperation, presence of task for and/or steering committee, legislative policies concerning marine invasives, stakeholder cooperation and partners, volunteer involvement, presence of a comprehensive research program, early detection and monitoring programs, presence of ballast water laws and vessel inspection. Places with satisfactory attempts to control marine invasives such as Washington State and New Zealand were analyzed first. A data table showing the different plan elements and study locations was created to compare sites based on available information. Where information could not be found, fields were left blank.

Each element was rated with a number that correlates to level of effort within that element at that location. The amount of effort put in at that location was determined through research. These rating were summed to create an overall number rating of each place. The higher the number, the more elements were utilized with more effort. A study site's success preventing or managing marine invasives was based on specific examples of eradication, control or prevention (when examples were available). Specific examples of success were then compared to the rating produced from this research to support validity of the rating method. The most important elements of a plan were determined based on conclusions from research and supporting literature. It was then determined whether the most crucial elements were part of the Maine Marine Invasive Species plan and if not, which ones could be incorporated to strengthen the plan. Suggestions were made based on these findings. Elements of successful green crab management plans outside of Maine were also analyzed and suggestions were made as to how to improve Maine's management efforts.

## **Findings**

Most agree that marine invasive species are an increasing threat to ecosystems and economies worldwide, with no location immune to introductions due to multiple transportation vectors dispersing them. Despite this, some places such as North Carolina and Maryland have no plans in place combat this spread. As previously mentioned, all states in the U.S. are covered under general federal laws but in most cases these are not sufficient and control and eradication attempts have been unsuccessful. However, on the other end of the spectrum are Washington

State, Australia and New Zealand. These places have almost all of the elements of a successful aquatic invasive species management plan. The study sites found to have the highest ratings are New Zealand, Washington State and Australia (Appendix 2). Determining success or failure of a plan or control attempt proved challenging. This is coupled with the fact that there are few recorded complete eradications of marine invasions. However, for the purposes of this project, success was measured based on examples of complete or partial eradication or control attempts and lack of invasions in places that are susceptible to commonly spread marine invasive. Therefore, according to literature and case studies and based on eradication attempts and successes, these three places were determined to be the most successful in their efforts. The elements that were examined to determine success will be discussed below using examples to compare study sites and plan elements.

### **Public Education Campaign**

One key element of an aquatic invasive species (AIS) plan is public education. Informing the public is crucial in limiting the spread of marine invaders, to help monitor invasive species and to encourage civic engagement. Public education can vary from one page on a state's website to widespread campaigns including educational materials, training programs, conferences and hotlines. The most successful management programs in Australia, New Zealand and Washington have widespread education campaigns with all of these elements. For example, New Zealand has a hotline that citizens can call to report sightings and a publication called Biosecurity Magazine that informs the public on recent marine invasive efforts. Other areas with widespread education campaigns on marine invasive species include Massachusetts, Florida, Hawaii and the Maritimes, Canada. Interestingly, Florida does not have a statewide AIS management plan but many smaller plans covering different regions of the state. Different regions have invested varying level of effort this way. Some states have widespread education campaigns concerning freshwater plants and animals and terrestrial organisms but very little concerning marine. New York State is one example of this. South Carolina also has a satisfactory education campaign in place but it is focused on freshwater plants. Maine, Rhode Island and Connecticut have limited education campaigns with no hotlines and few methods of educating the public past limited information on their state or university websites. In these states informed parties seem to be limited to educators and professionals working in fields that are affected by marine invasives.

## **Volunteers**

Educating the public on marine invasive species is essential in collecting information on their introduction and spread. However, it is also an important way to ensure that volunteers will be knowledgeable and invested when they are needed to carry out some aspect of the plan. In most places, financial involvement in combatting marine invasive species is limited. Therefore, volunteers are essential tools when it comes to monitoring and rapid response. Washington, Prince Edward Island (green crab and tunicate efforts), New Zealand, Australia and Massachusetts are several places that have extensive volunteer networks in place.

## **Early Detection and Monitoring Program**

Once a marine invasive species is established, management and control are nearly impossible if the organism isn't detected. If the introduced species is capable of surviving the biotic and abiotic conditions of the habitat it will likely spread and reproduce. Once the range has expanded and the species is well established, it is almost impossible to eradicate it. Therefore, early detection is essential. Some locations have early detection and monitoring programs put in place to catch any introduced species right away. These early detection programs are proven to be most successful when they target specific species that are easy to identify (Muir, 2011). These programs often involve a network of volunteers that annually or biannually survey for invasives and/or a hotline for citizens to report any invasives that they might come across. These systems have been shown to catch introductions early. Massachusetts, Washington, South Carolina, Rhode Island, parts of Florida, California, New Zealand, the Maritimes and Australia are places that have these programs in place. Hawaii, New Jersey, New York, Maine and Connecticut are places that do not have established early detection and monitoring programs (some of these places do have early detection and monitoring for freshwater plants and animals but not marine; Connecticut does biological surveys but they are not invasive specific).

Programs vary from place to place. New Zealand has the most widespread program with three main early detection and monitoring groups. The first is a targeted surveillance program which began in 2008 and focuses in on ports and marinas of first entry for international vessels. This program targets five marine pests that have potential to impact New Zealand's marine environment. The program is undertaken by the National Institute of Water and Atmospheric Research and occurs in 11 locations twice yearly. There is a public portal that houses the data (New Zealand Government, Non-indigenous Marine Species, 2013). The second, the pathway

surveillance program, involved surveys for baseline information at 13 commercial ports and three marinas between 2001 and 2004. The program performed a second round of surveys to monitor changes (New Zealand Government, Marine Biosecurity - Monitoring and Surveillance, 2013). The third is a passive surveillance program that consists of public lists of notifiable pests, diseases and unwanted organisms, pest and diseases hotline, incursion investigators who investigate pest and hotline reports and everyone in New Zealand being watchful (New Zealand Government, Biosecurity Surveillance, 2013).

Massachusetts does not have a comparably expansive program but similarly, has a single shared data system that is maintained by MIT Sea Grant called the Marine Invader Tracking Information System. The Salem Sound Coastwatch Monitoring Effort also leads a regional monitoring effort that monitors five coastal communities (much less than New Zealand) (MIT Sea Grant, 2009). Early detection and monitoring is less coordinated in Massachusetts than in New Zealand and the distribution of AIS in Massachusetts is poorly understood.

Washington has made a strong attempt to monitor invasive species introductions. Over 300 vessels are boarded and inspected every year (Plues, 2012). Green crabs are one species that were detected early on thanks to monitoring efforts. When European green crabs were discovered on Vancouver Island, British Columbia, a joint effort with Washington quickly resulted in removal. Over 100 sites in Puget Sound are monitored for the presence of green crabs by volunteers that are trained by Washington Department Fish and Wildlife Staff (Smith S. S., 1998). Trained staff and volunteer effort is one way that this successful program overlaps with New Zealand. New Zealand, Massachusetts and Washington have regional monitoring efforts in place as well.

### **Rapid Response Plan in Place**

If and when an aquatic invasive species is detected it can be difficult to properly and quickly identify it and take action to control it. A rapid response plan is essential for success in this situation. A rapid response plan outlines steps taken starting before the detection of an invasive species through a decision process that may culminate in an attempt to eradicate the species before it becomes established in the new habitat. It is essentially a plan B when prevention measures have failed. While monitoring and early detection programs are important, they are somewhat useless if a rapid response plan is not put in place. Removing an introduced

invasive species requires great effort and often involves multiple party involvement, funds and appropriate laws to support needed actions. The three main components of a rapid response are:

1. Processes and plans to guide response actions
2. Tools with which to respond
3. The capability and resources to carry out the response (Hewitt D. W., 2004)

Interestingly, many places have AIS management plans but have not developed rapid response plans. States without plans are Massachusetts, South Carolina, Rhode Island, New York, New Jersey, Hawaii and the Maritimes, Canada. Most of these places acknowledge the importance of creating a rapid response plan but for a variety of reasons (mostly lack of available funding) have not created plans. Maine has two rapid response plans, one for plant protocol and one specifically for fish and other fauna (this plan is mostly geared toward freshwater fish). Also, Maine does not have a monitoring and early detection protocol and it is unclear whether the rapid response plan has ever been used and whether it would be useful. One of the problems with the existing Maine Rapid Response Plan is that it does not have the third important part of the plan: capability and resources to carry out the response. Therefore it is unlikely that, if utilized, it would be successful (Maine Department of Inland Fisheries and Wildlife, 2006).

Alternatively, Australia, Washington, Connecticut (draft), parts of Florida, California and New Zealand do have rapid response plans. In Australia, the National System for the Prevention and Management of Marine Pest Incursions has an emergency response system set up called the Australian Emergency Marine Pest Plan which is thorough and contains all three of the primary listed components. There is also an Emergency Eradication Operational Response pending approval of the National Management Group. As part of this, rapid response manuals are currently under development that will specifically deal with green crabs, among other species. This was commissioned by the Australian Government Department of Agriculture Fisheries and Forestry. The National Introduced Marine Pest Information System rapid response toolbox contains a range of eradication options. There are also methods that outline how to rapidly gain access to funding if needed. This emergency response plan also highlights specific actions to be undertaken by members of the emergency response team and outlines specific phases from activation of the plan to completion (Natural Heritage Trust, 2005). Thorough rapid response plans are crucial to preventing the spread of marine invasives.

## Species Specific Management Plans

Australia also has specific management plans in place for a number of potentially invasive species, including the green crab. These plans include practical management approaches to prevent, control and manage impacts. It also includes contingency plans for new incursions and recommendations for public awareness strategies. One additional and important part of the plan is recommendations for future research and development and estimated budgets and resource requirements to implement the plan (Aquenal Pty Ltd, 2008). New Zealand also has an action plan for green crabs but it is much more limited and more educational. This is partly because green crabs have not yet invaded New Zealand; the country is being proactive in keeping an eye out for green crabs as they are a potential threat (Ministry of Fisheries, 2001).

When green crabs first invaded Washington in 1998, there was a quick response from the Governor and the Legislature in the form of emergency funds (Fund 001-4, Appropriation Code 612-4) that led to initiation of a monitoring program and control actions. A European Green Crab Task Force was also established at this time. In 1999, the Washington State Legislature directed the Washington Department of Fish and Wildlife to develop a long-term monitoring and control plan for the European Green Crab. In Willapa Bay and Grays Harbor, green crabs were eradicated by 2002. Washington Department of Fish and Wildlife continues to work with British Columbia to prepare for the potential spread of green crab populations in the Puget Sound, the Strait of Juan de Fuca and the San Juan Islands. Over 100 volunteers have been trained to survey and identify green crabs. The fact that there is regional cooperation in this case should be noted as it likely contributed to management success (WDFW Fish Management Program, 2014).

Despite a spike in green crab population numbers in the 1950s that wiped out much of the clam fishery, no action plan or monitoring system was created for green crabs in Maine. The U.S. National green crab action plan has many similar elements to the Washington and Australia plans, including suggestions for control, however there is no evidence that it has been utilized and may be too broad to be used by individual states (Kern, 2002).

For the most part, places that have developed and utilized species-specific and/or rapid response plans seem to be effective in managing introductions while places without have not had similar success. It should be mentioned that there are a number of factors that come into play when attempting to control invasive species populations, one of which is that if the introduced species has any natural predators, population numbers are often naturally kept low, as in the case

in Washington. This means that rapid response plans cannot exclusively take credit for success in invasive species control although it has been proven that they can help.

### **Ability to Seize Private Property**

One important element of a rapid response plan in effectively eradicating a recently introduced marine species is the ability to seize private property such as docks and marinas for the purpose of destroying or removing the invasive. Without this level of power, in some cases, eradication is incomplete and thus unsuccessful. The only case studies included in this report where invasive control personnel had the ability to seize private property were in New Zealand (in an attempt to eradicate tunicates) and in Australia (in an attempt to eradicate the black-striped mussel, *Mytilopsis sallei*).

#### **Example:**

In Cullen Bay, Australia in 1999 the black striped mussel was discovered during a routine inspection. This species of mussel has been known to destroy pearl farms, choke drainage and sewage systems and increase the cost of using and maintaining marine equipment in addition to reducing biodiversity. Experts theorize that it was brought in on the hull of a yacht. Once observed, efforts moved quickly. The harbor where it was discovered had a double lock-gate system and Cullen Bay was quarantined by the Northern Territory Fisheries Division. The area behind the lock gates was chlorinated. The entire marina and storm water drains in the area were also chlorinated. Divers systematically searched nearby marinas and found more mussels at several sites. These areas were quarantined and treated as well. All vessels that left the presumed marinas around the time of infestation were located, inspected and hauled out for more than a week to kill all encrusting organisms. Following the treatment of the areas, sampling panels inspected each location regularly for more than a year to make sure that there weren't any invasive mussels present. The effort was deemed a success due to support from all levels of government and the community, early detection, rapid action, legal capacity to enter, seize or destroy private property, the ability to isolate the infested water bodies from the local marine environment the ability to track exposed vessels and pre-existing information on chemical treatments for related taxa. Collateral damage was that everything was killed in the three areas that were treated with chlorine but they were already compromised, polluted areas so it was considered worthwhile. If the ability to seize or destroy private property was not present, this attempt would not have been successful (Locke & Hanson, Rapid Response to

Non-Indigenous Species, 1. Goals and History of Rapid Response in the Marine Environment., 2009).

### Specific Legislative Policies

One major shortfall of many Aquatic Invasive Species Management Plans is that they don't have sufficient legislative backing and authority to follow through on any implemented laws and programs. As previously mentioned, there are some international and federal laws and policies in place but many of them are voluntary and there is no authority to oversee and support them. A combination of international, federal and state laws are required to adequately limit and control marine invasive species and unfortunately many states do not have any specific state legislation in place to combat marine invasive species. Maine is one place that does not have any specific legislation in place to protect against marine invasive species despite a strong freshwater and plant invasive program. New Jersey and Florida also do not have specific legislation in place for marine aquatic invasive species.

Another challenge, in many cases, is inconsistent terminology used to refer to “non-native”, “invasive species” and “aquatic invasive species”. For example Nonindigenous Aquatic Nuisance Prevention Control Act of 1990 defines “invasive species” as: “*non-native 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.*” While the International Union for the Conservation of Nature defines them as: species that “*become established in natural or semi-natural ecosystems or habitat, that is an agent of change and threatens native biological diversity*” (Shine, Williams, & Gundling, 2000). When the definition isn't clear, scientific and measurable, comprehensive management can differ.

Coastal aquatic invasive species policy is most effective when focused on intercepting introductions because sometimes prevention is the only line of defense. As a result, legislation surrounding aquatic invasive species primarily deals with transport vectors. However, it is not always enforced. For example, California has established one of the most rigid and comprehensive ballast water management programs in the world. They were the first state to create mandatory ballast water regulation in 1999. This Marine Invasive Species program regulates ballast water exchange and reporting requirements. Under California's program, if vessels do not hold their ballast water they must exchange it 200 nautical miles offshore if they



are from outside of the Pacific Coast Region. If the vessel is from a port within the Pacific Coast Region, they must exchange ballast water 50 nautical miles from shore. There is a comprehensive monitoring and reporting program associated with this. Exemptions are given to this for specific reasons such as safety risk or vessels of the armed forces. Additional regulations concerning ballast water exchange include:

- 1) Discharge the minimal amount of ballast water needed in California waters.
- 2) Minimize discharge/uptake in areas that may directly affect marine sanctuaries, marine preserves, marine parks or coral reefs.
- 3) Minimize uptake in areas known to have infestations of non-native, areas near a sewage outfall, areas of toxic algal blooms, areas of turbid waters and at night where bottom dwelling organisms rise to the surface.

Additionally, ballast water management logs must be submitted for each vessel at port of call. These logs are required to include information on voyage ports of call, ballast water information and ballast water exchange information. In 2006, California began requiring that vessels adopt performance standards for the discharge of ballast water. These require that there are “zero detectable” organisms greater than 50 micrometers and fewer than 0.01 living organisms per milliliter for organisms between 10-50 micrometers. These regulations are much stricter than international standards. California has also offered grants to sponsor programs working to develop treatment technologies for ballast water to kill organisms without negatively impacting the environment. Unfortunately, so far none have met standards. Therefore, samples are taken of ballast water and sediment from at least 25 percent of vessels (Muir, 2011).

Under the 1993 Biosecurity Act, New Zealand has a similar set of regulations in place; the only legal option for ballast water exchange is in the open ocean. New Zealand also has a similar requirement as California in that ships must keep data logs and there are large fines if any of the information is found to be false. However, in both places, data from the Vessel Ballast Reports are rarely validated and therefore, the regulations are not always enforced (Carlton, 2003; Government N. Z., Reprint: Biosecurity Act 1993, 2013).

Unfortunately, California’s strict regulations are only for large vessels and don’t manage hull fouling. Alternatively, New Zealand has very stringent hull fouling regulations. They require

boats with significant fouling to haul out and clean their bottom at an approved facility. New Zealand requires that no cleaning can take place in New Zealand waters unless it occurs at a cleaning facility where all water and waste is collected and disposed of on land. Additionally, commercial vessels must follow a hull maintenance program where they receive regular dry dock inspections and cleanings. And finally, if a vessel is moored at one New Zealand Port for a significant amount of time, a diver must inspect the bottom before it can move to another port (Government N. Z., Marine Biosecurity - Vessel Cleaning, 2011; Cook, 2011).

Washington State has also implemented a Ballast Water Work Group and management scheme with a similar structure to New Zealand and California. They reached 100% ballast water report filing in late 2010, they are currently meeting the 90% Government, Management, Accountability and Performance compliance target for vessel arrivals into Puget Sound. In Washington, the AIS prevention and enforcement programs that were developed by the legislature in 2005 are nation-leading. One of their accomplishments is that since 2008, the Washington Department of Fish and Wildlife (WDFW) performed a total of 2,955 watercraft inspections at mandatory AIS Check Stations. Ninety-seven (3.5%) of vessels were infested with AIS. However, like California and other US states, funding cuts have hurt the program (Plues, 2012). Like New Zealand, the WDFW and the shipping vessel industry are working to develop a pilot project to identify and test viable ballast water treatment options (Smith S. S., 1998).

Other locations have laws in place to control other transportation vectors, often based on past managed invasive species. For example, South Carolina has legislation in place to control aquarium species transport and pet trade as well as nursery and landscape businesses. However, this mostly concerns freshwater and terrestrial invasive species (South Carolina Aquatic Invasive Species Task Force, 2008). In the Maritimes, most invasive species management policies are under the introductions and transfers permitting process, in the aquaculture trade transfer vector. Hull fouling is not controlled in the Maritimes (Locke A. , Hanson, MacNair, & Smith, 2009).

In international, federal and state policy, there are laws concerning marine invasive species but there are gaps, inconsistencies and redundancies. However, any program whose managing task force, panel or steering committee is composed of or run by the legislature has more legal power than one without. For example, New Zealand and Australia have significant power, especially behind rapid response actions, because there were mandated and organized at

the government level. This seems to be a key component to any real legal control in a successful marine invasive species program.

## Funding

Available funding varies considerably in the world of marine invasive species management. Any state, region or country with large funds has staff and organized programs in place to combat invasive species and is ultimately the most successful in their research, education, monitoring and management efforts. It is often difficult to weed out specific funding to combat marine invasive species so this report will compare general invasive species funding (including terrestrial and freshwater).

New Zealand spends a hefty sum combating invasive species. The Future Funding of Biosecurity Services website states that \$320 million was spent in 2003/04 in direct costs preventing invasives from arriving in New Zealand and managing them once established. Seventy-seven percent of funding came from general taxation, 22% by a third-party charge and the residual was from rates. Notably, \$22,537,000 was spent on publicly funded research and \$2,412,000 was spent on law enforcement. Furthermore, at least \$50,000 was spent on marine invasive management which includes eradication, containment or management of these pests (Government of New Zealand, 2009).

Australia also allots large funds to invasives. They spent at least \$10.96 million on national control plans. Ballast water exchanges and delays to shipping cost \$6.99 million and operation of ballast water framework cost \$2.91 million (Aqual Pty Ltd, 2008). Similarly, California spent \$39,234,928 in fiscal year 06/07. In that year, \$1,080,000 was spent on the Marine Invasive Species Program and \$2,013,000 was spent on Marine Invasive Species Program – Commercial Vessel Vectors. An additional \$144,500 was spent on aquatic invasive species Monitoring and Inspection Grants. California has provided state funding in the past through user fees, visitor taxes and the general fund (Muir, 2011).

The Maritimes has a different funding structure for marine invasives. Since 2005, there has been an employee of the Department of Fisheries and Oceans in place to coordinate Aquatic invasive species management, and receive and follow up on reports from the public and industry. This is a fulltime position and is mostly focused on combatting tunicates (Locke A. , Hanson,

MacNair, & Smith, 2009). Additionally, in 2004, Canada developed an Invasive Alien Species Strategy for Canada that was approved by federal, provincial and territorial resource ministers. This federal budget provided \$85 million over five years to support actions focused on enhancing preventative measures. Five million over five years went to the Invasive Alien Species Partnership Program (IASPP). Over a five year period, the IASPP received project proposals requesting a total of almost \$40 million. Funded projects focused on the priority areas of prevention, early detection, rapid response and management. A total of 141 projects were funded, targeting 277 aquatic invasive species with a total investment of \$4.6 million. For each dollar invested, almost two dollars were provided by project proponents and their partners. Although this funding was for all invasive species in Canada, the Prince Edward Island Aquaculture Alliance and the Cape Breton University Project U.F.O. Monitoring and Public Education Program about Invasive Alien Aquatic Species were recipients of the funding. In 2010, this funding was approved for phase two, an additional five years (Environment Canada, 2005). Overall, Canada has not invested as much in their invasive species management program as New Zealand and California.

Hawaii's invasive species program has a similar funding structure to Canada's. The Hawaii Invasive Species Council (HISC) disperses funds annually for their priority areas: invasive species prevention, control, outreach, and research. General funds are supplemented with special funds from the Natural Area Reserve Fund (which receives revenues from the conveyance tax levied on the sale of property in Hawaii) and the Legacy Land Conservation Program. Unfortunately, the HISC does not have a dedicated funding source and must rely on legislative appropriations from year to year. In fiscal year 2009, total funding was \$4 million but due to the recession, legislative general funding was cut and in fiscal years 2010, 2011, 2012 and in 2013, funding was less than \$2 million. Notably, most of this funding goes to prevention and management of terrestrial invasive species (Hawaii Invasive Species Council, 2014).

Washington State may be the most successful at maximizing limited resources while experiencing major budget cuts. There was a 40% cut to the Washington Department of Fish and Wildlife Aquatic Invasive Species prevention and enforcement programs between 2007 and 2012. Their federal funding for ballast water management, Atlantic salmon and general AIS management was cut from roughly \$150,000 per year to \$26,000 per year. Washington received

\$29,861 in federal funding in 2011. This is much lower than countries such as New Zealand, Canada and Australia. Washington supplements this funding with roughly \$160,000 spent on tunicate management per year and \$32,000 in general funds spent on green crab monitoring. Additionally, direct AIS prevention and enforcement program funding is roughly \$85,000 per year in the state (Plues, 2012).

Any state or region in the U.S. that gets their aquatic invasive species management plan approved by the Aquatic Nuisance Species Task Force is eligible for federal funding under Section 1204 of the Aquatic Nuisance Species Prevention and Control Act. Therefore, many states have been motivated to create plans (Aquatic Nuisance Task Force, 2012). In the United States, roughly \$1.095 million in total federal funding is split between all states with Aquatic Nuisance Species (ANS) management plants. At this time there are a number of states that have completed their plans but have not obtained monies past the funding needed to complete their plan. For example, Connecticut received funding from the National Sea Grant College program and the Connecticut Department of Environmental Protection to develop their management plan but have not received any additional funding for aquatic nuisance species projects (Connecticut Aquatic Nuisance Species Working Group, 2006). Massachusetts is a similar example (Massachusetts Office of Coastal Zone Management, 2002).

Other funding methods include state agencies, such as the Bureau of Invasive Species Management, that provide cost-share programs to counties to further leverage state funding. New Jersey has such state agencies. Also, New York partially funds invasive species programs through a real estate transfer tax. Additional, stable, sources of funding can come through boat, RV, ATV, fishing and hunting licenses as well as species importation permits. USDA grant and partnership programs such as Wildlife Habitat Incentive Program are available as well. Additionally, the US Fish and Wildlife Service provides 'Partners for Fish and Wildlife' grants that are often used for invasive species management where, for example, in New Jersey this is the case (Clef, 2009). Again, this is not specific to aquatic or marine invasive species. In conclusion, while funding is essential to combat marine invasives, funding is an increasingly limiting factor in management efforts in many places.

## Comprehensive Research Program

Understanding dispersal mechanisms, biology, ecology and behavior of invasive species is important when planning management or control of introductions or established invasive species. Locations examined in this report varied considerably in this regard. Some places have no comprehensive aquatic invasive species research program in place (for example, Florida, New York and New Jersey), others have completed limited rapid aquatic invasive species assessment surveys (Massachusetts) while others have regular, ongoing studies concerning aquatic invasive species. Washington is one state with ongoing green crab and ballast water treatment studies in place. South Carolina and New Zealand also have ballast water treatment studies in place and specific studies on particular marine invasive species that threaten their waters. There is some on-going research in Connecticut and Maine but this is mostly through the University systems and the Department of Marine Resources and is fairly disjointed. Another example is that the Maritimes has a comprehensive tunicate research program underway. California, Hawaii, New Zealand and Australia have invested in marine invasive species research on specific-species as well as general invasives work. NOAA Sea Grant and the Smithsonian Environmental Research Center as well as the United States Geological Survey and the Nature Conservancy are some organizations contributing to expanding knowledge of aquatic invasive species. The University system, including the University of California, also contributes significantly to aquatic invasive species research. For example, in 2006, the University of California-Davis researchers developed methods to control the invasive, *Sabellid* polychaete (Muir, 2011). Comprehensive research programs on marine invasives have been proven to contribute to proactive management of these species.

## Regional Cooperation

Marine Invasive Species know no boundaries so regional cooperation is vital in consistent and effective management. There are a number of attempts at regional planning around the world. Some examples include the Northeast Aquatic Nuisance Species Panel, the Gulf and South Atlantic Regional Panel on Aquatic Invasive Species and New Zealand's efforts are regional. Additionally, Washington State works across country boundaries with British Columbia.

## Recommendations and Conclusions

Maine does an adequate job of monitoring and controlling freshwater aquatic plants but there are few coordinated efforts to control marine invasive species underway. As warming waters and increased potential transport vectors exist in Maine, marine invasive species should be more seriously considered given their potential impacts. It is acknowledged that the nature of marine environments (for example: natural dispersal, limited access, open systems) makes it difficult to prevent and control marine invasives. Therefore, the state would be well served to increase efforts to prevent introductions and control colonized marine invasive species. There are multiple elements of a successful marine invasive species management program missing in Maine. A number of lessons can be learned from marine invasive species control efforts in other parts of the world and the following are recommendations for Maine based on successful efforts elsewhere.

### State of Maine Invasive Recommendations:

*Note: These recommendations are meant to be attempted concurrently, when possible, and are in no particular order.*

- Invasive species management plans and rapid response plans need to be created for **marine** species. Most existing aquatic invasive species management is not geared toward marine and therefore is not utilized. Additionally, the Governor-appointed Green Crab Task Force should not be dissolved. This should be a group that leads the ongoing effort.

### Coordination -

- Continue to build marine invasive species efforts under the Maine Department of Marine Resources. This department should work to better coordinate efforts and be the starting point for all collaborations, research and control efforts.
- There should be at least one or two staff working under this department focused on marine invasive species.
- The regional Northeast Aquatic Nuisance Species Panel could prove to be extremely helpful in coordinating work on green crabs. Increased involvement in this panel is suggested.
- List of potential invaders should be developed for Maine.

### **Funding –**

- The Department of Marine Resources should be in a position to allot federal, state and private funds to marine invasive species efforts.
- It is acknowledged that funds for this type of work are essentially non-existent at this time. Some stable, sources of funding could come through boat, RV, ATV, fishing or hunting licenses as well as species importation permits.

### **Monitoring –**

- Information clearing house or hotline based at the Department of Marine Resources that individuals could call to report invasives would be a great way to increase widespread volunteer monitoring. Imap or Vital Signs program could continue to be developed to serve this need.
- On-going monitoring for all potential marine invasives at numerous sites along the coast of Maine would strengthen the effort. This method has proven extremely successful at preventing marine invasions in other parts of the world including New Zealand. This would also be a great way to track population fluctuations in existing non-native marine species.

### **Seizure of Private Property-**

- Changing policies to allow for the seizure of private property for the purpose of rapid eradication of marine invasive species is one policy that has proved useful in other places.

### **Research -**

- The University of Maine at Orono, Maine Invasive Species Network is well positioned to become the center for a comprehensive research program on marine invasives. This University is already involved in this work but could expand their efforts past food science and could potentially include more public outreach.



## **Policy -**

- Transport vectors could be better monitored and controlled in Maine. Further regulations restricting ballast water, pet and aquaculture trade and allowed species would help. Having a list of restricted marine animals allowed in Maine (like Hawaii), would be helpful.
- The Department of Marine Resources should continue to manage ballast water discharges, compile a list of Maine facilities that hold marine organisms that have potential for accidental introduction, examine ways to prevent the spread of species from Maine to other regions and propose changes to regulations regarding the transport of aquaculture species within state waters. The Department of Marine Resources should also work to regulate the importation of live marine organisms.

## **Using Lessons Learned to Combat Green Crabs in Maine**

Despite numerous efforts to tackle the green crab problem from various angles, state funds have not been allotted to fight the problem. No green crab management plan or rapid response plan has been formulated or utilized. At the time of this report, a \$38 permit is required to harvest green crabs for profit in Maine although the Department of Marine Resources has recently issued Green Crab Special Exemption permits to allow individuals to fish green crab without submitting landings reports. A license is not required for personal consumption but investment (such as traps, bait and a boat) is needed to fish green crabs making it difficult for the average citizen to contribute to green crab control in this manner. Additionally, despite an effort at coordination at a Sea Grant organized Green Crab Summit in Orono in late 2013, few official efforts (other than the state appointed task force) have been made to organize and coordinate all existing efforts. This has led to gaps in effort in the Maine fight against green crabs.

## **Green Crab Recommendations for Maine:**

If the state could enact even some of the previously mentioned recommendations for marine invasive species management in Maine, management of green crabs would be more possible. However, in addition to the above recommendations, below are some recommendations for the fight against green crabs in Maine based on lessons learned from other locations' attempts to control this invasive. The green crab problem has proven so vast and difficult to control (given

failed eradication attempts in other places) but the literature supports a multi-faceted action plan to control green crabs including, but not limited to the following ideas (*Note: the following recommendations are in no particular order*):

- A specific Maine green crab management plan could help to coordinate green crab research and control efforts and make them more proactive rather than reactive. Considering a Gulf of Maine ecosystem with Green Crabs as a major ecosystem player and making decisions to protect or manage other parts of the ecosystem may be a way to look at this problem. The national Green Crab Management Plan could prove useful in this endeavor, although it would need to be catered to better fit Maine's political, economic and ecological structure.

#### **Research –**

- At the time of this report, there have been no known recent concerted efforts to study or monitor the effect of green crabs on lobsters and salt marshes in Maine. However, some have observed negative interactions between the two species. In summer 2013, because of a catch consisting of only green crabs, lobstermen were forced to move their lobster traps away from areas where they once caught numerous lobsters. It is hypothesized that green crabs crowd the lobster traps, going after the fresh bait before the lobsters can get to the trap, out competing the lobsters. One study completed in 2006 found that in six of eleven trials, green crabs caught and consumed juvenile lobsters. This proves that there is potential for green crabs to affect lobster populations and should be more closely examined (Rossong, Williams, Comeau, Mitchell, & Apaloo, 2006).
- Astounding numbers of green crabs have been observed inside “burrows” in salt marshes. It is unknown whether these burrows have been created by the crabs but it is clear that they inhabit them. Large chunks of salt marsh have been observed falling away due to these burrows fracturing the marsh. This has caused significant erosion in some places. Learning more about this may help determine how to better protect the marshes (Rousseau, 2014).

- Another area that has not been adequately considered is an ecosystem study on what the Gulf of Maine ecosystem might look like if green crab numbers are not controlled.
- An area of study that might be useful is the effect of green crab predation on birds. Because many shore birds consume the same food as green crabs, it is possible that green crabs are outcompeting birds. This could have unknown effects on shorebird populations. Some fishermen have observed that since green crabs have flourished, birds no longer frequent traditional feeding grounds (Rousseau, 2014).
- Further research on timed molting of green crabs and meat extraction may prove valuable.

#### **Policy -**

- Much like Maine, Canada has had trouble creating a market for green crabs partly because of limiting crab fishing licenses (Maclean, 2013). Therefore, to make it easier for fishermen to catch and sell green crabs, the state should alter or remove this license. Increasing and encouraging trapping could potentially make a dent.

#### **Volunteer Effort -**

- Bailey Bowdon suggested at the Green Crab Municipal Workshop on March 28, 2014 that planning one or two state wide “catch days” per month. A massive volunteer effort could be coordinated to catch as many crabs possible in a day, maximizing volunteer effort.

#### **Disposal/Market Creation -**

- Continue to work with composting firms to dispose of any caught green crabs. Some examples of composting firms that will take green crabs are:
  - City of Portland at Riverside Recycling, Maine Waste Solutions
  - Coast of Maine, Machias
  - Dubois Compost, Arundel
  - Knox Ridge Farm, Thorndike
  - Ecomovement d/b/a/ Mr. Fox Composting, Eliot

- Benson Compost, Gorham
- Many agree that continuing efforts to develop a market for green crabs is an acceptable use of resources. There are mixed feelings on whether aquaculture feed, exporting green crabs overseas or finding a way to market green crabs for human consumption in the northeast is a financially feasible option. However, if all parties looking at this problem combined resources, they may find a way to solve this problem. Pet food and lobster bait are two options that should be more seriously considered.
- More closely examining markets in the green crab's native range could help solve some of Maine's problems in developing a market.

### **Monitoring -**

- On-going monitoring should not be a priority (especially with limited resources available) but it would be helpful to use schools, the Gulf of Maine Research Institute's Vital Signs program or an organization already in place to track population trends in Maine overtime. This could be especially helpful in areas where green crabs are not as prevalent.

### **Education**

- Green crab education and outreach do exist in Maine as articles frequent newspapers across the state. Most local fishermen, non-profits and policy workers are well aware of the problem and many are getting involved. However, a more coordinated effort, in the form of a common forum or organization from the green crab task force could achieve this goal. Also, increasing education on proper disposal of green crabs for any interested fishermen may be important and DMR could potentially head this up (for example, disposing of the caught and killed crabs on land rather than at sea).

### **Fencing and Netting**

- Fencing and netting are laborious and may not be financially feasible for the large area of mud flats and eelgrass beds. However, in an attempt to save the soft-shell clam fishery in Maine, use of this technique should be considered by towns that can

afford it in vital clam and eelgrass bed areas. Because of federal endangered species requirements (specifically sturgeon), large area fencing will be limited and therefore, will have limited success. Therefore, netting might be a better option for smaller towns.

## **Conclusion**

Marine invasive species management is complicated and challenging. Prevention is the first line of defense and there are ballast water regulations in place at international and national levels. However, these attempts to prevent introduction often fall short. Places such as New Zealand and Australia have major marine invasive species preventative measures in place from strict ballast water management laws to significant funding. New Zealand, Washington state and Australia were found to put the most effort in to the widest range of elements required in a successful marine invasive species management effort. Maine's rating was mid-range, supporting that there are holes in the state's marine invasive species management efforts. Some suggested actions for Maine are to come up with a marine specific management and rapid response plans as well as come up with some funding source such as a small tax on boaters or recreational vehicle users. While green crabs are currently such a serious problem in Maine, there is much that can be learned from other places that have faced similar marine invasive species challenges. The spread of marine invasive species is difficult to prevent and control, especially with changing climate and ecosystem structures worldwide. However, there are efforts that can be made to better manage invaders and by doing so, protect lucrative fisheries, habitats and ecosystems.

## **Appendix 1**

### **Data Table Summary**

All study sites analyzed for this project had some form of Aquatic Invasive Species Management Plan except for Florida. The following is a brief summary of each study site:

#### **Massachusetts**

Massachusetts does not have a rapid response plan but does have some available funding (MIT Sea Grant). Massachusetts also has an expansive public education campaign that involves an interactive website (MIT Sea Grant), posters and there have been several workshops in this state. One important effort that Massachusetts is involved in is regional cooperation. Massachusetts also has a comprehensive early detection and monitoring program. The Massachusetts Office of Coastal Zone Management (CMZ) leads AIS detection and monitoring efforts through the Marine Invader Monitoring and Information Collaborative. In addition, CMZ trains interested groups to use a standardized monitoring protocol. Data is kept in single shared system maintained by MIT Sea Grant. Salem Sound Coastwatch also does some monitoring (an annual effort that involves monitoring in five coastal communities). Massachusetts is involved in the regional monitoring effort: the Marine Invader Tracking Information System (MIT Sea Grant College Program). However, Massachusetts does not have any additional regulations in place to control marine invaders and in ballast water and eradication attempts of green crabs have failed.

#### **Washington**

Washington State stands out as a place that is making a diverse and strong effort to combat invasive species. They have a very strong education campaign, a rapid response plan, available state and federal funds, various stakeholder cooperation, volunteer involvement and early detection and monitoring programs. Folks in Washington have also passed 14 bills since 1998 concerning aquatic invasive species, including ballast water management requirements such as mandatory reporting and open water exchange (Plues, 2012). They are also involved in regional efforts with parts of Western Canada, specifically concerned with monitoring the spread of green crabs. Washington responded rapidly to the introduction of the European green crab. The early implementation of monitoring and control efforts in infested bays has helped keep population numbers down (Washington Invasive Species Council, 2009).

## **South Carolina**

Most aquatic invasive species work and funds in South Carolina revolve around freshwater plants. However, South Carolina is part of the Gulf and South Atlantic Regional Panel on Aquatic Invasive Species. There are some effective legislative policies in place (mostly dealing with transport of aquarium species, nursery and pet trade and landscaping) and some research programs have been developed. These research programs include participation in a national monitoring study of invasive decapod crab species, research on developing methods to detect invasive pathogens in ballast water and work on the Asian oyster (*Crassostrea gigas*). They have some early detection and monitoring programs in places as well. However, they have no specific ballast water management policies in place. There is also very little volunteer effort concerning marine invasive organisms in this state and almost no public education campaign. There have been no successful efforts to combat marine invasive species in South Carolina (South Carolina Aquatic Invasive Species Task Force, 2008).

## **Rhode Island**

The strongest elements of marine invasive species work in Rhode Island are volunteer involvement, a comprehensive research program and early detection and monitoring programs. These are mostly thanks to help from state universities. A Rhode Island Sea Grant College Program Rapid Assessment Survey that took place in 2000, 2003, 2007 and 2010 turned up 13 established marine invasive species and seven potential invasives. Rhode Island also has a specific Ballast Water Act. Rhode Island's public education campaign is mostly based around the Rhode Island Natural History Survey but academic researchers and agency personnel contribute on an ad hoc basis. Rhode Island received funds from the US Fish and Wildlife Service in 2008 to be used on monitoring but they do not have any other significant funding. Rhode Island has several statutes in place to combat invasive species. One that is unique is the authority to enter lands and waters for purpose of survey. However, there is no strong authority to restrict introduction and order removal of aquatic invasive species in Rhode Island at this time. There is no list of banned organisms and no ability to restrict interstate trade of organisms. There is also limited legislative power. As with some other states, there is some legal mechanism potentially adaptable to a streamlined permitting process to control aquatic invasive species but only when there is an imminent peril to the public health, safety or welfare (McNally, 2006). Rhode Island

does not have any successful documented marine invasive species eradication or control attempts. The Rhode Island Aquatic Invasive Species Plan states that more research needs to be done on commercial uses and biological controls before they come up with a way to manage green crab populations and Asian shore crabs (Aquatic Nuisance Species Task Force, 2007).

### **Connecticut**

Connecticut has a strong public education campaign and some research programs but few other coordinated efforts concerning marine invasive species. They have no specific marine invasive species early detection and monitoring programs past biological surveys conducted by the Marine Fisheries Division and no specific ballast water policies. Connecticut also completed a draft of a rapid response plan but it is unclear whether it was finalized or not. In Connecticut there haven't been any recorded marine invasive species eradication or control efforts (Connecticut Aquatic Nuisance Species Working Group, 2006).

### **New York**

New York State has put little effort toward prevention and management of marine invasive species. There is a public education campaign in place in New York but most of the state's efforts have gone toward freshwater (specifically the Great Lakes) and terrestrial because of their small amount of ocean frontage. New York gets some funding for aquatic invasives but almost none of it goes towards marine. New York partially funds invasive species programs through a real estate transfer tax. This state is part of a regional effort but they don't have any rapid response plan in place. Additionally, there is no research program in place for marine invasives here and no early detection and monitoring programs (New York Sea Grant Aquatic Invasive Species Website, 2013).

### **New Jersey**

Despite the fact that New Jersey has an aquatic invasive species management plan, much like Maine, there is no mention of them in the Selected ED/RR species list. Green crabs are only mentioned twice in the entire document. Any work is on aquatic plants but there are virtually no efforts being made toward fighting marine invasives at the state level. Additionally, the New



Jersey Invasive Species Council page hasn't been updated since 2009 (New Jersey Invasive Species Council, 2009).

## **Florida**

Despite the lack of a statewide Aquatic Invasive Species Management Plan, Florida has a number of aquatic invasive species efforts underway. Florida has 17 different Invasive Species Management Areas and the Invasive Species Partnership works to educate the public and coordinate between different areas. Some of these areas have rapid response plans in place as well. Most of the aquatic efforts involve freshwater fish and plants but there are some marine efforts, specifically involving lionfish (*Pterois volitans*) (Everglades Cooperative Invasive Species Management, 2009-2011). Efforts to educate the public on the negative effects of the invasive lionfish include an outreach committee, newsletter and annual invasive species summits. For the lionfish there is a research program and an Early Detection and Distribution Mapping System. One part of the state held a non-native fish round up at one point as well. Florida has been successful in attracting significant federal funds to supplement state spending for invasive species (including \$36 million from USDA grant programs) but most of this money goes to fighting terrestrial and freshwater invasive species. In addition, the Bureau of Invasive Species Management provides cost-share programs to counties to further leverage state funding (Florida Invasive Species Partnership, 2012).

## **California**

California is a state that has made significant attempts to combat marine invasive species. This is relevant because in San Francisco Bay, 97% of the marine species present are invasive. There are public education campaigns, a rapid response plan, significant federal and state funding, regional cooperation, stakeholder cooperation, research programs, early detection and monitoring programs, and some ballast water management attempts. Transport vectors are the major focus of efforts in California so their monitoring efforts and ballast water management regulations are the most powerful. There are some examples of control and eradication attempts in California. In 1999 the Parasitic Polychaete (*Tererasabella heterouncinata*) escaped outside a mariculture facility. Thanks to limited dispersal ability of the benthic larval stage, it stayed in a small area and was detected early. Rapid response began within weeks of detection. There was follow up

monitoring in the following two years. Additionally, there was cooperation between private, public, regulatory and scientific community. Another example is the attempted control of the Chinese mitten crab (*Eriocheir sinensis*; first detected in 1992). In 1998 one million crabs were collected. The state built “Crabzilla”, an 18-foot high traveling fish screen, to collect crabs that were ground into fertilizer. Mitten crab numbers declined after 2001 and in 2005 they had a minimal presence in the watershed. Folks in California have also put effort into removing green crabs through trapping (State of California Department of Fish and Game, 2008).

## **Hawaii**

Hawaii has been struggling with a slew of invasive species that have greatly altered their ecosystems and natural environment. Therefore, it is no surprise that they have a strong education campaign, state funding, some legislative policies, stakeholder cooperation, volunteer involvement and research programs in place. However, many of these efforts are terrestrial based. There is no early detection and monitoring program for marine invasive species and no rapid response plan in place here. A large majority of the available funding goes to terrestrial invasives as well. There is an invasive species committee on each of the Hawaiian Islands with paid staff and field crew. They work with government agencies, nongovernmental organizations and private businesses. They have many partners, for example partners of the Invasive Species Committee on the Big Island include: Hawaii County, Hawaii Department of Agriculture, Hawaii Department of Land and Natural Resources: Division of Forestry and Wildlife, Hawaii Volcanoes National Park, Kamehameha Schools, Kohala Watershed Partnership, Malama O Puna, Office of Hawaiian Affairs, The Nature Conservancy of Hawaii, Three Mountain Alliance, U.S. Fish and Wildlife Service, U.S. Geological Survey, U.S.D.A. Forest Service and the University of Hawaii College of Tropical Agriculture & Human Resources. However, the aquatic invasive species management plan states that there is unclear or conflicting agency jurisdiction and little contingency or cooperative planning. The Hawaiian Invasive Species Council was created to combat this issue and was signed into law (Shluker, 2003). There has been some work to control marine invasives. For example, attempts to smother invasive snowflake coral on Kauai began in Port Allen. This effort is still ongoing. Thirty four species of marine fish have been introduced into Hawaiian waters, and at least twenty of these have become established (Englund and Eldredge 2001; Eldredge and Carlton 2002). Of those established, thirteen species have been

authorized, purposeful releases. Around seven species were accidental introductions (Englund and Eldredge 2001). In addition, between 1955 and 1961 Hawaii introduced 11 species of fish as potential fish food. Notably, there is a hotline in Hawaii for residents to call and report invasives. Hawaii has not been able to get around Federal trade agreements. This means that known pests are regularly imported into Hawaii. Much of the goods coming into Hawaii goes uninspected so pests can arrive via passenger, cargo, ballast water, military and postal etc., limiting invasive management.

## **New Zealand**

New Zealand is known worldwide as being effective in preventing the introduction of marine invasive species. New Zealand has efforts underway for every element of marine invasive species prevention and control that were looked at in this study. Additionally, New Zealand has species specific plans in place to combat marine invasives. For example, there is a plan for green crabs even though they haven't yet been introduced. They have effectively prevented colonization of this species, despite the fact that New Zealand is in their potential range. However, there was a failed eradication attempt on tunicate, *Didemnum vexillum*, in 2001. The failure was largely due to the fact that the tunicate was improperly identified as a native species initially and that there was no rapid response plan in place at the time. However, monitoring continues and there was a large public education campaign associated. One notable aspect of New Zealand's efforts is that they have legal authority to seize private property. New Zealand spends a significant amount of money on their biosecurity efforts. Existing funding for biosecurity services provided by all government agencies was: \$319.5 million in 2003/2004. In addition, rate payers contribute between \$50 million and \$60 million in funding toward regional pest management strategies and private individuals and organizations spend additional sums on biosecurity (previous study estimated \$180 million per year). Also, seventy-one million dollars was spent on pest and weed management programs for conservation purposes. 2010 Biosecurity act changes state that an estimated \$719 million is spent in direct costs preventing pests from arriving in New Zealand and managing them once there. Biosecurity has significant legal authority as it is its own department of the New Zealand national government. They have very strict ballast water management laws in place as well (New Zealand Government, Non-indigenous Marine Species, 2013).

## **Maritimes, Canada**

The big effort in the Maritimes has been to control invasive tunicates. There has been a large public education campaign and some federal and provincial funding (there is a staff member in a marine invasive species management role). Notably, there is no rapid response plan in place. Canadian Federal ballast water laws are comparable to the ones present in the U.S.A. In Canada, there is a Canadian Action plan under Fisheries and Oceans Canada to fight aquatic invasive species introduction and spread. However, there are no provincial-specific aquatic invasive species management plans in place. On the topic of tunicates, there has been stakeholder cooperation, a targeted tunicates research program as well as monitoring. Despite strong efforts, folks in the Maritimes have not been entirely successful in controlling them and eradication was not successful. Suppression of abundance and partial containment to quarantined areas were obtained. Management took place through the introductions and transfers permitting process but this only addresses the aquaculture transfer vector. Therefore, no complete control of dispersal is possible. There have been some small concentrated efforts to control green crabs but they have been limited (Locke & Hanson, Rapid Response to Non-Indigenous Species, 1. Goals and History of Rapid Response in the Marine Environment., 2009).

## **Australia**

Australia has strict invasive species management laws and strong marine invasive combat efforts in place, comparable to New Zealand's. When it comes to green crabs. Their efforts have been significant. They have a national green crab management plan, a strong public education campaign, a rapid response plan (that could be utilized with green crabs), funding, a research program and early detection and monitoring programs as well as stringent ballast water management laws. Green crabs have only been established in Tasmania but have been largely kept out of other parts of the country. The Intergovernmental Agreement on a National System for the Prevention and Management of Marine Pest Incursions addresses the agreed funding mechanisms for implementing national control plans (Aquenal Pty Ltd, 2008).

## Appendix 2

Table 2. Data table summarizing element ratings and overall score per location.

	Aquatic Invasive Species Management Plan in Place? (Y/N)	Public Education Campaign (0=none, 1=representational, 2=moderate, 3=expansive*)	Ability to seize or destroy private property (Y=1, No)	Rapid Response Plan Created (Yes, No)	Federal, state, regional or town funding (0=none specifically for marine invasives, 1=limited, 2=moderate, 3=substantial**)	Regional Cooperation (Y=1, No)	Creation of task force and/or steering committee to implement plan (Y=1, No)	Effective legislative policies put in place to halt further spread and introduction (0=none, 1=some, 2=many***)	Federal, state, local, private and stakeholder cooperation and partners (0=none, 1=some, 2=all)	Volunteer involvement (Y=1, No)	Comprehensive research program developed (0=none, 1=species specific, 2=general aquatic invasive, 3=both)	Early Detection and monitoring programs (0=none, 1=yes on, but not utilized, 2=present and utilized)	Area (state/region)/count of specific ballast water management laws and vessel inspection laws (1=satisfactory, 2=substantial)	Rating (higher = more elements)
Massachusetts	Yes (October 2002)	3	0	0	1	1	1	1	1	1	1	2	0	12
Washington (Y)	Yes (October 2001)	3	0	1	2	1	1	2	2	1	2	2	2	19
South Carolina	Yes (2008)	1	0	0	3	1	1	1	2	1	1	2	0	14
Maine	Yes (2002)	1	0	1	1	1	1	0	1	1	1	0	0	8
Rhode Island	Yes (2007)	1	0	0	2	1	1	1	2	1	1	2	1	14
Connecticut	Yes (2006)	2	0	1	1	1	1	1	1	1	2	0	0	10
New York	Yes (2002)	2	0	0	2	1	1	1	1	1	0	0	1	10
New Jersey	Yes (2009)	2	0	0	1	1	1	0	1	1	0	0	0	3
Florida	No	3	0	1	3	1	1	0	1	1	1	2	0	14
California	Yes (2008)	2	0	1	3	1	1	1	2	1	2	1	1	16
Hawaii	Yes (2003)	3	0	0	3	0	1	1	2	1	2	0	1	14
New Zealand	Yes	3	1	1	3	1	1	2	2	1	2	2	2	21
Maritimes, CA	Canadian AIS plan (2008)	3	0	0	2	1	1	1	2	1	1	2	0	14
Australia (specifically GC management plan)	National Green crab specific management plan	3	1	1	3	1	1	1	1	1	2	2	2	18

\* 1 = information sources available on the internet only, 2 = information available at marinas and some effort to hold informational sessions,

3 = multiple organizations spreading awareness through schools, community meetings, educational materials and word of mouth

\*\* 1 = less than \$10,000, 2 = less than \$1 million, 3 = greater than \$1 million

\*\*\* 1 = less than 3 broad national laws, 2 = multiple state and/or species specific laws dealing with Marine Invasives

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