Island Invasion: The Silent Crisis in Hawaii

Sophia Janssen

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Island Invasion: The Silent Crisis in Hawaii

A Look into Invasive Species Management & Policy Changes to Protect the Islands

Sophia Michelle Janssen

In Partial Fulfillment of the Requirements for the Degree of
Bachelor of Arts in Public Policy Analysis/ Environmental Analysis

POMONA COLLEGE
Claremont, California
April 26, 2019

Presented to:

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Donald C. McKenna Professor of Government & Economics
Claremont McKenna College

W. Bowman Cutter
Associate Professor of Economics
Pomona College
DEDICATION

To my family, for always pushing me to sit down and write, and for supporting me in all my interests, wherever they may take me. I am grateful for you and there is not a day that goes by where I do not feel lucky and loved.

To my friends at Pomona College, from Maui, and from all across the world, thank you for inspiring me with your creative minds, challenging my ideas, and enriching my life more than you know.

I would like to dedicate this thesis to Lloyd Loope, the leader of the fight against invasive species in Maui and extending this battle to all the Hawaiian Islands. Your tireless efforts have protected Hawaii for generations to come.

February 4th, 1943 – July 4th, 2017

“Nature is a language and every new fact one learns is a new word; but it is not a language taken to pieces and dead in the dictionary, but the language put together into a most significant and universal sense. I wish to learn this language – not that I may know a new grammar, but that I may read the great book which is written in that tongue”

- Ralph Waldo Emerson
ACKNOWLEDGEMENTS

I am grateful for the guidance and support of both my thesis readers, Professor Ascher & Professor Cutter. Bill, I want to express the immense appreciation I feel for taking the time to break down each sentence, examine my thoughts, and transform my ideas into reality. I cemented my love for environmental policy in your Processes of Environmental Policymaking course and have not looked back. It only took me a few years, but I think I have finally cracked your sense of humor and genuinely enjoyed your curiosity to learn something new from anyone, anywhere. Professor Cutter, your perspective on the environment and rational deliberation of environmental issues changed the way I value my surroundings. Environmental Economics was the qualitative substance that I craved to approach these problems from a new standpoint, and this class was my favorite course in my four years at Pomona College. Thank you for your help and for your feedback.

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<td>Animal and Plant Health Inspection Service</td>
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<td>ASIF</td>
<td>Alien Species Inspection Facility</td>
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<td>AQ</td>
<td>Animal Quarantine Division</td>
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<td>BIISC</td>
<td>Big Island Invasive Species Committee</td>
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<tr>
<td>CBD</td>
<td>Convention on Biological Diversity</td>
</tr>
<tr>
<td>CBP</td>
<td>U.S. Customs and Border Protection</td>
</tr>
<tr>
<td>CERCLA</td>
<td>Comprehensive Environmental Response, Compensation &amp; Liability Act, Superfund</td>
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<tr>
<td>CGAPS</td>
<td>Coordinating Group on Alien Pest Species</td>
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<tr>
<td>CMS</td>
<td>Convention on Migratory Species</td>
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<td>DAR</td>
<td>Hawaii Division of Aquatic Resources</td>
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<td>DBEDT</td>
<td>Hawaii Department of Business, Economic Development and Tourism</td>
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<tr>
<td>DLNR</td>
<td>Hawaii Department of Land and Natural Resources</td>
</tr>
<tr>
<td>DOD</td>
<td>Department of Defense</td>
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<tr>
<td>DOFAW</td>
<td>DLNR Division of Forestry and Wildlife</td>
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<td>DOH</td>
<td>Hawaii Department of Health</td>
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<td>DOT</td>
<td>Hawaii Department of Transportation</td>
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<td>DOTA</td>
<td>Hawaii DOT Airports Division</td>
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<td>EEZ</td>
<td>Exclusive Economic Zone</td>
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<td>EPA</td>
<td>U.S. Environmental Protection Agency</td>
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<td>ESA</td>
<td>Endangered Species Act</td>
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<td>EU</td>
<td>European Union</td>
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<tr>
<td>FY</td>
<td>Fiscal Year</td>
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<tr>
<td>GSP</td>
<td>Gross State Product</td>
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<tr>
<td>GM</td>
<td>Genetically Modified</td>
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<tr>
<td>HAL</td>
<td>Hawaii Ant Lab</td>
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<tr>
<td>HDOA</td>
<td>Hawaii Department of Agriculture</td>
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<tr>
<td>HDOT</td>
<td>Hawaii Department of Transportation</td>
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<tr>
<td>HEPA</td>
<td>Hawaii Environmental Policy Act</td>
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<tr>
<td>HIBP</td>
<td>Hawaii Interagency Biosecurity Plan</td>
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<td>HISC</td>
<td>Hawaii Invasive Species Council</td>
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<tr>
<td>HNSO</td>
<td>Hazardous Substances and New Organisms Act of 1996 (NZ)</td>
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<td>HTA</td>
<td>Hawaii Tourism Authority</td>
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<td>IPIF</td>
<td>Institute of Pacific Islands Forestry</td>
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<td>ISCs</td>
<td>Invasive Species Committees of HI</td>
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<tr>
<td>IUCN</td>
<td>International Union for the Conservation of Nature</td>
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<tr>
<td>JBMS</td>
<td>Joint Border Management System (NZ)</td>
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<td>KISC</td>
<td>Kauai Invasive Species Committee</td>
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<td>LFA</td>
<td>Little Fire Ant</td>
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<td>LLC</td>
<td>Legacy Land Conservation Funds, DLNR</td>
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<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>MAC</td>
<td>Melastome Action Committee</td>
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<td>MBTA</td>
<td>U.S. Migratory Bird Treaty Act</td>
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<td>MPI</td>
<td>Ministry of Primary Industries (NZ)</td>
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<td>MISC</td>
<td>Maui Invasive Species Committee</td>
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<tr>
<td>MoMISC</td>
<td>Molokai Subcommittee of MISC</td>
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<td>NAR</td>
<td>Natural Area Reserve</td>
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<td>NOAA</td>
<td>U.S. National Oceanic and Atmospheric Administration</td>
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<td>NPS</td>
<td>National Park Service</td>
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<td>NZ</td>
<td>New Zealand</td>
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<tr>
<td>NZCS</td>
<td>New Zealand Customs Service</td>
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<tr>
<td>OISC</td>
<td>Oahu Invasive Species Committee</td>
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<tr>
<td>PBARCS</td>
<td>Pacific Basin Agricultural Research Center</td>
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<tr>
<td>PCSU</td>
<td>Pacific Cooperative Studies Unit</td>
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<tr>
<td>PI</td>
<td>Plant Industry/ Division</td>
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<td>PQ</td>
<td>Plant Quarantine</td>
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<tr>
<td>ROD</td>
<td>Rapid Ohia Death</td>
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<tr>
<td>RSPB</td>
<td>Royal Society for the Protection of Birds (UK)</td>
</tr>
<tr>
<td>SCOPE</td>
<td>Scientific Community on Problems of the Environment</td>
</tr>
<tr>
<td>UH</td>
<td>University of Hawaii</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
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<tr>
<td>USDA</td>
<td>U.S. Department of Agriculture</td>
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<td>USFS</td>
<td>U.S. Forest Service</td>
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<td>USFWS</td>
<td>U.S. Fish and Wildlife Service</td>
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<tr>
<td>USGS</td>
<td>U.S. Geological Survey</td>
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<td>WCC</td>
<td>World Conservation Congress</td>
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Chapter 1: Introduction

Overview

Keeping out invasive species\(^1\) may, upon first review, seem like a trivial environmental cry from ecologists and deep environmentalists; a belated wish to return to an undeveloped world where nature was pristine. However invasive species create problems that impact all of us and can have far more severe consequences than changing a stunning landscape. These problems are heightened in islands like Hawaii, where the fragile ecosystems have developed over centuries of evolution and adaptation. The introduction of a disease-carrying mosquito can put the people of Hawaii at risk to many vector-born illnesses and create an epidemic, taking human life. The introduction of invasive plants that outcompete native plants for water can reduce the water available for homes and businesses, as well as restrict the flow in native streams, putting indigenous fish at risk. The loss of coral reef from alien algae or the arrival of snakes may lead to significant drops in tourism, which for Hawaii is one of the largest facets of the economy. Introduced non-native species tend to outcompete the relatively sheltered island species, therefore leading to a decline in biodiversity. In fact, this process of decimation and change in many locations has already begun, with the native forests confined to small swathes of isolated upper slopes of the volcanoes. Rates of extinction are increasing, costs to eradicate invasive species are rising, and still the silent invasion continues, with an onslaught of species accompanying each boat or plane.

Because the presence of these unwanted species can significantly damage and alter the ecology of the Hawaiian Islands, there needs to be a targeted effort to mitigate the worst effects.

\(^1\) Invasive species is defined throughout this thesis as defined by Bill Clinton in Executive Order 13112 in 1999: "Invasive species" means an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health.
It is important to outline the ways in which invasive species can harm Hawaii, as well as provide a detailed study of the scale of the problem.

This thesis will examine several research questions surrounding best practices for invasive species management policy in Hawaii. The ensuing chapters will seek to answer a variety of questions. What gaps exist in this policy, if any? What measures can be taken to prevent damages from invasive species in Hawaii? What role can government agencies play in preventing the negative consequences of these alien species on the people and land of Hawaii? What should the government role look like? What pathways introduce harmful nonnative species? What are the best practices for managing invasive species internationally?

To begin to answer these questions, the extent of the problem must be understood. The threat of invasive species can be examined in several fields, primarily how invasive species impact tourism, agriculture, ecology, and health. Once the major pathways have been identified, the thesis will examine Hawaii’s historic and current framework to preventing invasive species, to identify the strengths and weaknesses. Several case studies reveal certain aspects of the problem that may not have been explicitly considered in the current policy framework. Hawaii is not alone in its fight against invasive species, so the efforts locally will be compared and assessed along with other countries and islands, which are all attempting to improve biosecurity at their borders. Lastly, the case studies and country comparisons expose several policy recommendations, which are presented in consideration of the likelihood of adoption and the variety of funding scenarios. The resources attributed to invasive species in Hawaii are currently so minimal that any policy recommendations would require significant efforts on the part of the state legislature to prioritize biosecurity and the prevention of invasive species above other

---

2 See Appendix Figure 1 for a map of the Hawaiian Islands. Hawai‘i Island is commonly known as the Big Island and will be used throughout this thesis.
initiatives. The futures of Hawaii’s ecosystem, economy, and people are at risk until invasive species prevention is given the funding and updates needed to protect the islands for generations to come.

**Quantifying the Threats and Examining Introduction Pathways**

Understanding why invasive species pose a threat to all citizens necessitates a deeper dive into the primary pathways through which invasive species arrive in Hawaii and the resulting ramifications. The pathways identified in this thesis are known to cause noteworthy damage to Hawaii, but do not necessarily represent all plausible pathways of species introductions. Pathways refers to the means by which a species travels to Hawaii, either naturally (ex. wind, ocean currents) or through man-made avenues (planes, boats, people). The term vector is sometimes used synonymously with pathway but particularly centers on biological pathways, like organisms, which introduce pathogens, diseases and parasites (USDA, 2019). The pathways of entry into the state assist in the decision-making of where to allocate resources to reduce the worst impacts.

**Tourism: Packing People & Pests**

Tourism is crucial to Hawaii’s economy and funds the backbone of the budget, yet also brings in thousands of organisms each year. Tourism is by far the top industry in Hawaii, bringing in about 90 percent of the gross state product (GSP) (Jones, 2015). Perhaps not surprisingly, the state budget allocates many of its funds towards tourism-related initiatives, such as marketing and infrastructure near resorts, to maintain this revenue stream. In 2007, 7,627,819 people visited Hawaii (Beal, 2009). A decade later, the number of visitors to the state increased to 9,404,346 (Chun, Chun, Liu, & Patoskie, 2017). Approximately 60 percent of flight seats are occupied by passengers from within the United States, making it the largest market for visitors.

3 Hawaii’s Fiscal year is July 1st to June 30th.
(Chun et al., 2017). Between 69-91 percent of visitors come to Hawaii with the purpose of vacation, an important factor to consider when accessing the hazard of invasive species.

Most tourists visit Hawaii because it is a tropical paradise, with palm trees swaying in the breeze and pristine ocean waves crashing on the shore. An ever-growing portion of tourists want to explore the islands beyond their resort, to venture out into the stunning wilderness on hikes, ziplines, tours, and bikes. The National Parks Service (NPS) controls 30,000 acres of land across five islands as of 2016. The NPS estimates that it generates $400,200,000 in economic benefit from national park tourism and hosts around 6 million tourists per year (National Park Service, 2018). The growth of ecotourism and outdoor related activities constitutes a significant portion of visitor spending. From 17 Sustainable Certified companies in 2014, the number rose to 348 companies certified in 2019 (Trilogy Sailing LLC., 2014). These companies profit from the natural beauty of the island, and profits would significantly decrease with the loss of coral reefs, the destruction of native forests, and the transformation of the landscape by invasive species. Creatures such as sea lice, certain types of jellyfish, sand fleas, sand flies, stinging coral, and microorganisms could significantly alter the ocean’s attractiveness, changing tourists’ decisions on where to vacation (Berkowitz, 2017). The arrival of invasive species has changed some aspects of the local environment already, but the scariest considerations are what could arrive, resulting in a reduction in Hawaii’s tourism revenue.

Tourism is not distributed evenly across each of the main Hawaiian Islands. Oahu receives the majority of visitors, as many international flights must first land in Oahu before inter-island transfers (Figure 1). Oahu is equipped to handle many travelers and has customs policies to inspect bags for invasive species from abroad, but the outer islands do not.
Maui does not have an official international airport but the third and fourth largest visitor groups arrive from international destinations (Japan and Canada, respectively). However, Maui County officials are looking to attract more visitors from increasingly distant places, but also not considering the additional risk of new invasive species. Kahului Airport, Maui’s primary airport, is extending its runway to receive international flights (Imada, 2019). By 2035, an estimated 3.6 million tourists will pass through Kahului Airport per year (Imada, 2019). The Department of Transportation, Airports Division (DOTA) released a new plan in 2016 to extend the runway to account for larger airplanes but does not outline plans for new larger inspection facilities to inspect the increased number of baggage and cargo (L. Kawaoka, 2016). Flights from increasingly farther places will add a host of novel species to the range of possible introductions. Many areas of the airport will see substantial improvements because of the proposed plan, except the alien species inspection facility (ASIF), which will be moved but not expanded.

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4 The Kahului airport on Maui has only one direct international carrier, Air Canada.
More Canadians flew directly to Maui and outer islands versus directly to Oahu. Additionally, Southern Canada, where the majority of Canadians travel from, is a temperate zone. Temperate zones pose a large threat to Hawaii as temperate species are more likely to outcompete native species, completely disrupting a native ecosystem (Meyer & Cowie, 2010). Temperate species have a larger climate envelope, as they experience a sizable temperature range caused by seasons, versus the relatively stable temperature and smaller fluctuations in the tropics. Especially under a changing climate, these species are often better equipped to handle the extremes than tropical species and thus may overtake endemic species (to be explained in the “Ecological Impacts” subsection).

The U.S. West poses a similar threat as Canada to Hawaii due to the type of landscape that characterizes both regions. The west coast, comprised of California, Oregon, and Washington, is generally a temperate landscape. This information should prompt Hawaii to be equally if not more cautious about the arrival of tourists by boat from temperate locations like Canada and California than by plane.

Despite the large number of tourists each year, the actual threat they pose as carriers of large numbers of invasive species is small compared to other pathways, but the risks are still high. In a series of blitz inspections conducted in 2002, 42 items were destroyed out of the 4,644 intercepted items as these goods were “of concern due to pests” (Plant Quarantine Branch, 2002). Although 0.09 percent of all goods intercepted contained a potential threat\(^5\), the harm inflicted by even a few invasive species can be massive. Of 1,000 identified introduced species with established populations in Hawaii, the ecological and economic impact of these species is substantial, totaling millions in reparations (Daehler, Denslow, Ansari, & Kuo, 2004). The

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\(^5\) This particular study was based on the inspection of 1,897 commercial flights and 399,463 passengers in 2002 by the Department of Transportation (DOT).
number of introductions has increased greatly since 2002\(^6\) as more tourists, planes, and cruise ships arrive in Hawaii, but the potential of the 0.09 percent of invasive arrivals to do harm is dramatic, despite the deceptively small percentage.

**A Primary Pathway: Nurseries & Agriculture**

*Agriculture Introductions*

Another vector for the transmission of invasive species are the movement of plants and livestock, which can lead to the spread of invasive species from across the globe. The threat that pests and invasive plants can pose to agriculture prompted increased concern regarding invasive species pathways and often prioritized removing invasive species that were threats to agriculture over other species that pose a risk to health, tourism, quality of life, etc. Agriculture often prompted the beginning of inspections and biosecurity legislation especially in economies where livestock and crops contributed significantly to overall GDP (Hustedt, 2010). Goods transported for agriculture often are receptacles for hitchhiker organisms, species which arrive on the bodies of other species and inanimate objects that may be invasive.

Nurseries in particular form a disproportionately risky avenue for invasive species entry into Hawaii for smaller quantities of product; each plant is more likely to have a pest that will survive and establish a population that each person entering Hawaii. Nurseries in Hawaii are difficult to regulate due to the degree of inspection that would be placed on the inspectors to accurately uncover and prevent each hazard brought by the host species.

*Nurseries Introduction: A High-Risk Pathway*

The transit of plants and landscaping materials such as soil and fertilizer also has become a major pathway for invasive species introductions. The nurseries are encouraged to sell native

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\(^6\) The last blitz study was conducted in 2002 in Hawaii. A follow-up study has not been conducted in more recent years.
plants but many import houseplants and shrubs that are preferred by residents for a certain look, including exotic flowers, grasses, and flowering trees. The result of this demand for a certain exotic look in landscaping actually encourages nurseries and gardens to import plants that better fit that image, compared to more subdued native varieties. The issue with this trade is that the live tissue of the plants can carry various bugs and pathogens that are difficult to remove, or that may only emerge upon arrival. These hitchhiking organisms may prove to be more of a problem than the tree or shrub itself, which may be a non-native but not invasive species. For example, the coqui frog, a tiny quarter-sized frog from Puerto Rico, is believed to have arrived in Hawaii in the 1990s on a shipment of plants from Florida (Lin, 2014). The male frogs chirp at 90 decibels, which individually is about as loud as a garbage disposal or lawn mower, and collectively can create a cacophony of sleepless nights and depressing real estate prospects (Lin, 2014). The frogs also consume large quantities of endemic insects and arthropods, already pushing some bugs to precariously small populations and others to extinction. The shipment of soil containing fungi associated with the Rapid Ohia Death (ROD) disease in nursery plants have also spread the disease to other islands, killing acres of the native ohia tree (Ch. 3, Case Studies). Miconia, a large invasive tree from Central and South America, found its way to Hawaii via plant enthusiasts who brought specimens to private nurseries starting in 1961 (MISC, 2017a). The species is so invasive the roots can grow through asphalt and has spread to over 37,000 acres on Maui and 9,500 acres on Oahu. The seeds are easily spread by seabirds who fly between the islands. Therefore, nurseries are a concerning and prevalent pathway for invasive species to arrive and spread amongst the islands, as well as inflicting unnecessary damage to infrastructure, human welfare, and reducing biodiversity.

*Ecological Impacts of Various Species Arrivals*
Invasive species approaching Hawaii through planes or boats play a significant role in ecosystem functioning and negatively influence many native species, which hold both ecological and cultural significance, through resource competition, nutrient cycling, and faster growth rates. These characteristics, generally of r-selection species, allow invasive species to dominate due to the ability to produce large number of offspring, mature quickly, and adapt to a new region by eating a wide range of life.

Invasive Species Water Monopolies

Invasive species are generally less efficient in the host environment and may use more water than the evolutionarily adapted local species. In South Africa, another biodiversity hotspot like Hawaii, introduced Acacia and Pinus trees have reduced stream flow and simultaneously increased fire potential by increasing the drought stress on native trees (Pejchar & Mooney, 2009). Many invasive species often have deeper roots, higher evapotranspiration rates, and larger biomass, all of which make them more successful in drawing out water. Just two species, the yellow star thistle and the salt cedar, consume enough water to reduce the water available for their respective regions by 1.4-3.0 billion cubic meters of water each year (Pejchar & Mooney, 2009). Programs such as Working for Water in South Africa combat the loss of municipal water by employing workers to clear invasive species from streams and watersheds (Department of Environmental Affairs, 2019). These efforts, which have cleared three million miles of invasive species since 1995, also save the local government billions of dollars and replenish a resource that is often contested and scarce. However, the cost of labor raises the total monies needed for the program, and the likelihood of total eradication is low. The invasive Eucalyptus tree in Hawaii has been particularly success at dominating the water supply, yet Hawaii has not established a program like Working for Water to reduce its impact on groundwater availability nor has it banned Eucalyptus.
Island Fragility & Biodiversity Implications

Islands in general tend to incur more damages from invasive species than continents due to the susceptibility of their distinctive flora and fauna to invasions: “islands, in particular, have been the recipients of the largest proportional numbers of invaders” (Ewel et al., 1999; Pejchar & Mooney, 2009). Island species occupy specific niches which reduces competition and allows species to cohabitate despite the limited resources. Due to the remoteness of some island archipelagos, the rate of introduction of new species was relatively low, as species had to be able swim, float, or fly across thousands of miles of ocean. Hawaii is the most isolated island chain in the world, so the pre-trade rate of introduction was low as there was a low-probability of organisms dispersing across such a large geographic barrier (Mooney & Cleland, 2001; Western Pacific Regional Fishery Management Council, 2019). When invasive arrivals appear, the fragile balance is disrupted, and the idiosyncratic island species are replaced by more generalist species from continents and other locations. These generalist species often certain characteristics, such as r-selection, which increase the invasiveness.

In the globalized world, species interact that might never have come in contact with Hawaii naturally. Species from continents especially inflict the most damage on island communities, as depicted in the chart below.

![Chart showing frequency and severity of impacts of successful translocations of mammals.](image)
Figure 1.2: Impact of Nonnative Species on Native Species (Ricciardi & Simberloff, 2009)

Species translocated from a continent to a remote island (C-RI) inflicted the most damage, as seen in Chart A of the figure. 64 percent of species moved from a continent to a remote island inflicted damage on the native ecosystem (Ricciardi & Simberloff, 2009). These findings reveal that the movement of species beyond their native range can inflict harm, especially the movement of species from continents to remote islands such as Hawaii. As many of the travelers arriving in Hawaii come from the U.S. west coast, the potential for these species to be dangerous is high.

Several temperate species have already arrived in Hawaii from the U.S. West and are already impairing native refuges. The little fire ant (LFA), registered on Hawaii’s Top Ten Invasive Species List, likely has arrived in Hawaii via nursery plants shipped from the southeastern United States (Dennison, 2015). Black and Norway rats first arrived in Hawaii via Western introduction by ship in the 1780s and are estimated to destroy 20 percent of agricultural crops worldwide each year (U.S. Fish & Wildlife Service, 2018a). Fireweed, introduced via contaminated soil on the Big Island in the 1980s from the West Coast, has now become a widespread toxin for livestock and wildlife, with the ability to cause death and severe illness in full-grown cattle (Starr, Martz, & Loope, 1999, 1998). These species are just a few of many harmful temperate arrivals, with more organisms reaching Hawaii each year in cargo, livestock, and baggage.

The arrival of invasive species on islands may exacerbate some of the extinction and endangerment events caused by urbanization and development. Areas that were not previously isolated are frequently transforming into “virtual islands” where human activities have caused fragmentation of habitat and abridged the genetic health by isolating populations and preventing interbreeding (The Center for Biological Diversity, 2019). These islands within an island are
aggravating the already fragile conditions of the island communities, worsening the rate of extinction and the loss of island biodiversity. When invasive species arrive, the species contribute to the isolation of populations, increasing the chance of their own success at the expense of the native plants and animals.

All Paths Lead to Extinction

Invasive species are one of the many factors contributing to the “sixth wave of mass extinctions…the worst spate of species die-offs since the loss of the dinosaurs 65 million years ago” (The Center for Biological Diversity, 2019). This era of the “Anthropocene” is characterized by the drastic human influence on mass extinction rates, as the spread of invasive species through trade and human activity has only heightened the extinction rate in Hawaii (B. Cox, Moore, & Ladle, 2016). The natural background rate of extinction ranges between one and five species each year, while current rates of extinction are estimated to be 1,000 to 10,000 times the background rate (M DE Vos, Joppa, L Gittleman, Stephens, & Pimm, 2014; The Center for Biological Diversity, 2019). To add to the concern, these rates are calculated based on the amount of known extinct species, which means the true rate of extinction is probably underestimated given how many species have yet to be identified. A third of the world’s amphibians are at risk and frog trade is not well regulated, meaning frogs and amphibians are regularly exchanged between remote locations (Bittel, 2019). The current extinction rate for amphibians is estimated between 25,039 to 45,474 times the background rate (The Center for Biological Diversity, 2019). Why is the “amphibian apocalypse” causing such a stir? Amphibians, such as frogs and salamanders, are the “canary in the global coal mine” for other species implying that something is seriously wrong with the planet. The invasive species in Hawaii add to the risk of a global drop in biodiversity, which “could ultimately claim many other species, including humans” (The Center for Biological Diversity, 2019).
The loss of species is a national and global phenomenon as seven to 18 percent of U.S. known species are listed as endangered (The Center for Biological Diversity, 2019). However, Hawaii houses the majority of endangered species in the U.S.; 415 federally listed taxa out of the 1096 endangered species listed nationally are in Hawaii. 38 percent of endangered species in the U.S. are found in Hawaii on just 0.2 percent of U.S. land area (State of Hawaii 2019; Cox, Moore, and Ladle 2016, p. 173). The cause of such high rates of endangerment can be partially attributed to invasive species, as the populations of nonnative organisms has begun to overtake the island (Figure 3).

Figure 1.3: Distribution of the 17 Most Invasive Plant Species in Hawaii (Vorsino et al., 2014)
Hawaii is not alone in the record-breaking rates of extinction. 50 percent of the world’s primates are at risk of extinction while 68 percent of global plant species are disappearing (The Center for Biological Diversity, 2019). Causes of these extinctions are primarily the result of human activity, with some estimates as high as 99 percent of the current mass extinction crisis caused by humans (The Center for Biological Diversity, 2019). Human activity can threaten species by initiating habitat destruction, introducing invasive and exotic species, spreading diseases through globalization of trade, polluting water, air, and soil, and through agricultural practices which promote monocropping and reduce biodiversity. Hawaii is also at risk to invasiveness, perhaps more so than other places, because the islands’ biota evolved in relative isolation for 70 million years prior to Polynesian arrival (State of Hawaii DLNR and Division of Forestry and Wildlife 2017, p. 3). Invasive species play a large role in the extinction of species, and Hawaii’s geologic history furthers the probability of a colossal loss in biodiversity in upcoming years.

**Lessons from Past Invasive Species and Their Pathways**

Many species have been introduced and already damaged the land in ways that may be irreparable from a myriad of pathways. The introduction of rats to Hawaii by Europeans, such as the black rat and the Norwegian rat, have stunted and even lead to a decline in forests, as well as caused a loss of animal species (Meyer & Shiels, 2009). The introduction of gastropods, such as the giant African snail and the Rosy Wolf snail, have contributed to the loss of endemic terrestrial snail species and have been named some of the world’s most damaging pests (Meyer & Shiels, 2009). The Rosy Wolf snail feeds on smaller snails and slugs while the giant African snail has a large appetite which drives it to consume over 500 varieties of plants. Both rats and snails eat similar plant parts and reduce plant survival rates, reducing biodiversity in Hawaii.

Some invasive species do more damage than others. Eucalyptus species have large deep tap roots, which are able to extract massive quantities of water and are allelopathic, meaning the
chemical processes of Eucalyptus actually inhibit the growth of other plants (May & Ash, 1990). The leaching of deleterious chemicals into the soil shrinks the biodiversity in an area and allows young Eucalyptus plants to grow without competition. Feral pigs, introduced by Polynesians and hybridized with European boars, knock down ferns in the forest to eat the soft inner parts, contributing to erosion, and creating holes that fill with water and become habitat for disease-carrying mosquitoes (Pejchar & Mooney, 2009). The presence or introduction of these invasive species has larger risks attached to it perhaps than the arrival of an invasive flower. However, it is difficult to calculate this risk.

Given the enormous damage that has already occurred, what other species could be as risky as pigs or Eucalyptus? The difficult nature from that question comes from the trouble to accurately predict which species negative impacts will have as well as which species might have a small to indistinguishable impact (Ewel et al., 1999). How many new arrivals does it take to establish a stable population of invasive species? These estimates are difficult to make successfully but the risk of just one nonnative species becoming invasive could translate to millions in damages, explored further in Chapter 2.

**Marine Pathways**

*Cruise Ships and Ballast Water*

Cruise ships also comprise just over one percent of visitors to Hawaii yet have significant potential to injure Hawaii. Cruise ships brought 126,723 visitors to Hawaii in 2017 (Chun et al., 2017). Increasingly, tourists are flying to Hawaii and then boarding cruise ships, with 129,113 visitors in 2017. Therefore the true total of cruise ship visitors, combining those that arrive on the ship and those that first fly to Hawaii, is 255,846 (Chun et al., 2017).

The ships are a threat for a few main reasons. First, many ships intake ballast water in tanks to maintain the stability of ship and help the ship to accommodate changes in weight. The ballast
water, however, is a main transmitter of invasive marine species between ports. After a ship has balanced itself by the uptake of ballast water, usually in shallow regions, it will complete its journey and then discharge the ballast water from the first destination at its next stop. Zebra mussels are the quintessential case of the ballast water invasive species pathway. This species from Europe has covered the Great Lakes in thick invasive mussels which clog water systems, outcompete native mussels, and congest the ship’s system itself (Bruno, 2019). Ballast water also brings plant species like Eurasian Milfoil, which forms thick mats on the surface and prevents recreational activities. Most cruise visitors spend time on all four main islands: Oahu, Maui, Big Island, and Kauai (Chun et al., 2017). The inter-island travel of cruise ships also spreads invasions that may previously have been contained to one island. Cruise ships come from all around the globe. These ships may have contaminants on their hulls, known as biofouling, and in their ballast water that previously were not known to occur in Hawaii. The number of cruise ships pales in comparison to ships used for commercial activities, which are more numerous and may actually contain larger amounts of ballast water.

Commercial Ships

Commercial ships serve as the primary vector for aquatic species arriving to Hawaii. The connectivity of the global commercial shipping trade has led to a significant array of ships coming through Honolulu, as the business center of Hawaii’s economy and military activity. The commercial ships are very frequent and come from ports all over the world, as depicted by the map.
Figures 1.4 & 1.5: Map of Global Shipping Routes over One Year, with Hawaii in black (Plumer, 2016)

Figure 1.4 demonstrates the sheer volume of ships crossing the Pacific, with Hawaii at the epicenter of this traffic and often serving as a midway point between other destinations. The color of the transit line represents what the ships are carrying: pink for vehicles, green for gas, red for tanker, blue for dry bulk, and yellow for container. The red tankers transmit oil and represent the majority of the ships entering Honolulu, depicted in Figure 1.5. The bulk of that shipping route is oil, as Hawaii does not have abundant fossil fuels. The majority of ships are coming from the west carrying containers, bringing Hawaii its food products. Hawaii imports 90 percent of its food and imports 80 percent of all its goods, from furniture to clothing (Hawaii Department of Agriculture, Hawaii Department of Land and Natural Resources, H.T. Harvey & Associates, Kuiwalu, LLC, & Richard Hill & Associates, 2016). The Big Island receives mostly gas and dry bulk at its ports of Hilo and Kawaihae. Due to the Big Island’s distance from Honolulu, it receives more goods directly than other outer islands. This difference could explain why the Big Island has been exposed to more invasive species per capita than other regions in Hawaii. Maui on the other hand receives many of its goods indirectly, by way of Oahu or the Big Island. Inter-island travel is of particular significant to Maui and Kauai because of this unique
property in the shipping pathways, which blocks many of the invasive species from establishing on Maui or Kauai directly.

Beyond their ability to transmit invasive species, the commercial ships also emitted over one million tons of carbon dioxide per day in 2012, more than the countries of the United Kingdom, Canada, or Brazil in a whole year (Plumer, 2016). The amount of bunker fuel required to support this global commercial shipping industry is the root of a noteworthy influence on global warming, a further incentive to rethink the shipping trade to prevent environmental degradation.

Military Introductions

The U.S. military also plays a large role in the movement of ships and equipment across the Pacific Ocean. The movement of ships during World War II led to the spread and introduction of all sorts of alien invasive species, such as the brown tree snake from Papua New Guinea to Guam and unusual introductions like a two-foot long juvenile water monitor lizard at the Joint Base Pearl Harbor-Hickam (HISC, 2015b). There are between 11-20 military flights to Hawaii every day, which contain many pounds of cargo and passengers from remote regions (Ikuma, Sugano, & Mardfin, 2002). The military is supposed to inspect their own personnel, planes, and ships but the inspections seem to be feeble and limited. From 1981 to 1994, seven brown tree snakes were discovered on Oahu at military bases (Pearl Harbor, Hickam Air Force Base, Barber’s Point Naval Air Station, and Schofield Barracks (Oahu Nature Tours, n.d.). The state has 11 military bases and is second only to Virginia in proportion of GSP from military contributions (Hawaii Life, 2013; Kelly, 1998). The military’s primary presence is felt on Oahu, where 78 percent of personnel work at just four sites: Schofield Barracks, Pearl Harbor, Kaneohe Marine Corps Base, and Hickam Air Force Base (Kelly, 1998). All four sites have recorded invasive species introductions. To manage all its initiatives and activities, the military owns five
percent of the land in Hawaii, with the military owning a massive 21 percent of Oahu (Kelly, 1998). Although the number of military personnel in Hawaii has been decreasing due to less U.S. presence in Asia, the impact and scale of operations is still notable compared to other states (see Appendix, Figure 2). Training and maintaining military personnel in Hawaii are costly compared to other states, but an extended military body will likely persist due to the strategic location in the middle of the Pacific. The travel between U.S. bases in Asia, the South Pacific, and North America creates a pathway of species introductions, which is further opened by the lack of strict military self-inspection policies.

**Miscellaneous Pathways**

**Mail**

The mail that arrives in Hawaii is not able to be inspected by the Hawaii Department of Agriculture (HDOA) unless the post office suspects a package may contain a species or something illegal. The mail has become a way to send illegal exotic and invasive species and pets to Hawaii and to avoid interception at airports. 22,560 tons of shipments arrived in Hawaii in 2006 (John M. Knox & Associates, 2008). The mail arrives primarily by air on Oahu, and then is shipped by boat to other islands. People have been known to ship pest, such as snakes, and seeds that may spread and go undetected at border control.

**Chapter 2: Policy Choices**

**The Two Main Policy Choices at Hand**

What is Hawaii’s approach to invasive species? Based on the knowledge of the pathways that lead to introductions, how has Hawaii responded to the arrival of invasive species throughout history? The next section will go over the background of invasive species policy in Hawaii and how the issue gradually gained momentum in the public sphere. However, the
approach can be characterized by two main policy choices: the precautionary principle versus the cost-benefit approach, and a centralized versus decentralized organizational structure.

**Precautionary Principle versus Cost-Benefit Analysis**

In environmental legislation and regulation, there are two main camps for how to respond to an environmental problem. First, the precautionary principle is based upon a risk-averse strategy to limit the uncertainty of unknowns, to err on the side of caution by inserting regulations and strict boundaries until a problem is well understood. The 1992 Rio Declaration on Environment and Development defines the precautionary principle and approach as “where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation” (Science Communication Unit, University of the West of England 2017, p. 3). In risk management, based on the precautionary principle, the approach is to look at adverse outcomes and the probability of their occurrence to then calculate an appropriate response, adding cautious measures the less is known (Mehta, Haight, & Homans, 2010). For example, one percent of all nonnative introductions become invasive, which does not warrant the expense of preventing the population in a cost-benefit framework, but the precautionary principle would dictate that this adverse event should be avoided and prevented as little is known about which species will become the one percent (Williamson, 1996). The probability of the event occurring is so low yet the negative consequences of an invasive species arrival, such as a brown tree snake (see Ch. 4 Case Studies), merits the government spending its budget on preventing it; this framework is also used to approach spending with natural disasters and floods (Williamson, 1996). Even in cases where the species is not known to be invasive, the precautionary principle applied as a policy framework would implore that the border and pre-border prevention should assume the species is guilty until proven innocent. An application of this philosophy is the white list method, which
catalogs which species are permitted into the region instead of the black list approach of which species are not granted entry. Countries like New Zealand approach invasive species using the precautionary principle and white lists, to be explored further in Ch. 6.

Examples of the Precautionary Principle at Work

Examples of the precautionary principle include the European Union’s (EU) approach to pesticides and genetically modified organisms. The EU’s REACH Regulation of 1907, updated in 2006, requires chemical suppliers and manufacturers to prove the chemicals are safe and demonstrate how they communicate safe use to all users in the supply chain (Science Communication Unit, University of the West of England 2017, p. 15). This decision puts the burden of proof on the chemical creators themselves and prevents the spread of high-risk substances. The EU also enacted a moratorium on genetically modified (GM) crops in 1998, as the public was suspicious of the health impacts and little research had been conducted on the effects on biodiversity should GM seeds escape (Science Communication Unit, University of the West of England, 2017). Throughout the EU, field studies were conducted to examine GM food crops and the United Kingdom formed a committee on biotechnology to build the knowledge base. This example demonstrates a case where the level of uncertainty was high, and the government followed the precautionary principle in order to better understand the potential problem before it expanded into a larger issue. GM crops were ultimately approved in Europe but on a case by case basis, as several knowledge gaps still exist (Science Communication Unit, University of the West of England, 2017).

Cost-Benefit Analysis

The second option for Hawaii policy regarding invasive species is to apply cost-benefit analysis. Cost-benefit analysis only warrants a policy response once a problem’s cost outweighs the benefits, i.e. when the problem has become large enough that it deserves the attention of
national and state-level funds and legislative action. For invasive species management in Hawaii, a form of cost-benefit analysis has typically been the dominant approach, where the government waits until the species has caused massive destruction before beginning to eradicate it.

Economic modeling attempts to quantify a species’ contributions to biodiversity and the ecosystem in order to determine the best line of management: prevention or eradication. This approach focuses on the costs of preventing invasive species compared to the costs of controlling the species, and compares the costs to determine a course of action (Leung et al., 2002). The model combines economic and biologic components into the framework, which attempts to best represent the complexity of invasive species interactions. However, species can behave in uncertain ways and even a species that has never been characterized as invasive can become invasive in a new environment under different conditions (Ricciardi & Simberloff, 2009). Therefore, critics of this technique explain that even if a model were able to fully describe the complex interactions of species, it cannot confidently predict exactly how species will respond to these conditions. The model found that prevention was the best strategy in terms of maximizing social welfare and reducing costs to society, a result that would question why Hawaii does not spend more on prevention (discussed in the “Economics of Prevention” section) (Leung et al., 2002; Mack et al., 2000; Vorsino et al., 2014). However, the time frame considered for the cost-benefit analysis impacted the ultimate decision to act or not. In five years or less, which was used as an approximate for political terms, the optimal (cheapest) strategy was to do nothing (Leung et al., 2002). The strategy to do nothing until a certain threshold of an established harmful organism population is reached maximizes resources, as more of the invasive organisms are caught per hour spent, so it is a good deal for governments making budgeting decisions.

However, cost-benefit analysis is not the most ecologically sound. Current Hawaii examples demonstrate the practice of the “wait and see” approach. For the invasive tree Miconia,
cost-benefit analysis dictates that Maui, Oahu, and the Big Island that have large antagonistic populations should implement a population reduction program while Kauai, with isolated Miconia individuals, should wait to proceed as search costs are high for low yield (Burnett, Kaiser, & Roumasset, 2006). In this case, the range of results in decision-making came from the number of individuals removed per dollar spent, which shifted the choice at a certain sample size. More efforts are expanding to quantify environmental variables, such as the cost of the loss of water availability, to more accurately compare the true cost of not acting against invasive species that is not included in present approaches (Mack et al., 2000). Optimal control theory, the understanding that waiting for a certain population size is cheaper for eradication than funding a rapid response effort, ignores the long term impacts of invasive species and the future savings of prevention (Burnett et al., 2006). Doing nothing until the situation worsens does not take into account that even a small number of invasive species can cause harm and that the more the population grows, the longer it will take to restore these areas to pre-arrival conditions. The cost-benefit analysis therefore is opposed to the precautionary principle method as the latter would be costly yet generate, ecologically-speaking, better results in terms of invasive species.

Examples of Cost-Benefit Analysis in Environmental Policy

Cost-benefit analysis governs many U.S. environmental policies, including the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) and Safe Drinking Water Act of 1974. Both policies weigh the costs of leaving a contaminated waste site or waste source untreated and the resources needed to clean up these sites against the benefits of clean water to society, to an ecosystem, and/or to human health to determine a course of action. Cost-benefit analysis came to the forefront of environmental policy under President Reagan, who in 1981 made cost-benefit analysis a standard procedure (Andrews, 2017). The Clean Air Act of 1970 is another example of cost-benefit analysis. The costs of research and
implementing clean manufacturing technology ultimately were less than the benefits to human health from clean air, resulting in the adoption of stringent clean air policies to improve health. The cost-benefit analysis requires the knowledge of the impacts of various aspects included in the procedure, while the precautionary principle is meant to combat uncertainty. Therefore, for invasive species policies, it seems appropriate that the precautionary principle should be applied, as many of the impacts are hard to predict or quantitatively estimate in advance, as seen in Ch. 4 Case Studies.

Also, this methodology tends to work in tandem with the black list technique that places species on a prohibited list as they are discovered to negatively impact the environment. If the benefits outweigh the costs and the U.S. Environmental Protection Agency (EPA) decides to take action, the EPA may also try to ban certain chemicals that are contaminating sites (in the case of CERCLA for example) because the prevalence of these chemicals are adding to the EPA’s costs of clean-up (OECA US EPA, 2013). However, the EPA would only do so after it is known that these chemicals, or whatever the problem is, is discovered to cause harm. At that point, many areas may already have widespread problems with that chemical, and the EPA must retroactively work to improve the situation (OA US EPA, 2016). The black list can be difficult to enforce, as many cities may be violators but did not know they were in violation of federal chemical limits or be unable to address these laws in a timely manner due to the amount of effluence. The lack of foresight may create communities that have been consuming contaminated water or bathing in polluted lakes for generations before any information is revealed that these activities could lead to unfavorable health concerns and the inability on the part of the government to right this wrong.

The black list works well when certain items, such as chemicals or organisms, are known to be a threat. However, the white list helps to offset the uncertainty which accompanies many
(species, where little research exists, to be able to limit the possibility of the species causing harm.

**Centralized versus Decentralized Organizational Structure**

Another key policy decision that arises in invasive species policy is the utility of one agency in charge of invasive species management versus a cooperative interagency system. Hawaii currently has a decentralized organizational structure, where several state and federal agencies interact and overlap to cover invasive species administration. However, the result is varying mandates which do not all align to remove the same threats: “interagency arrangements designed to improve performance in one area might hinder it in another” (Kaiser 2011, p. 21). A benefit of an inter-agency system is that invasive species problems are complex and cross-cutting, so cooperation between agencies is important because all parties are affected. The multi-agency approach also may reduce competition between agencies or minimize policy fragmentation (Kaiser 2011, p. 2). An additional mode of public-private partnerships could be explored to manage invasive species in post-border eradication efforts, but this thesis focuses mainly on prevention policies and structures as either a multi-agency effort or run by one lead agency.

One agency in charge of invasive species has many positive attributes, including the guarantee of funding exclusively dedicated to that purpose as well as the accompanying staff and legal authority. However, one agency assigned to invasive species may not equally consider the concerns of all agencies affected by its decisions and may lack agency-specific knowledge of invasive species practices. New Zealand operates invasive species management through one central agency, the Ministry of Primary Industries Biosecurity Division, which has established the premier model for biosecurity in the world. One executive agency eliminates the tensions and conflicts of interest that may exist between agency mandates and reduces disagreements in times
of urgency (Kaiser 2011, p. 25). This approach may be crucial to the timely nature of intercepting species at Hawaii’s ports of entry and avoiding confusion in lines of communications and action. A centralized invasive species committee could help to reduce many of the issues Hawaii faces with unsuccessful policy in the current interagency system somewhat led by a group of advisors known as the Hawaii Invasive Species Council (HISC).

Given that Hawaii’s existing approach to the invasive species problem has been governed by the wait and see ethos of cost-benefit analysis, many invasive species have slipped through the cracks and caused millions in damage to the state. Therefore, the next section examines the ways in which an emphasis on prevention may change Hawaii’s outlook on invasive species to one of more caution and risk mitigation. As funding is an issue for effective invasive species policy in Hawaii, the following section will explore the financial figures for prevention versus eradication to determine which approach yields the most returns for each dollar spent.

**Economics of Prevention**

The philosophy behind Hawaii’s current invasive species policy framework is reactive, spending more money and resources on eradication and invasive species management (post-border) than prevention and interception (pre-border and border). Figure 6 epitomizes the past and current decision to fund emergencies and individual target species. This approach does not follow the Department of Land and Natural Resources’ (DLNR) advice: “[t]he minimal cost of supporting invasive species prevention and control should be weighed against the potentially devastating economic impact that widespread invasive species can have in Hawaii” (DLNR & Division of Forestry and Wildlife, 2015). To protect Hawaii against Miconia, a highly invasive tree covering Maui and Oahu, the state had spent over $672 million annually to attempt to remove the dense forests but in 2017 abandoned these efforts. The damage is magnified by the potential for species like Miconia to become a monoculture. The harm of the plant comes from
its shallow roots which increase water runoff, increase the likelihood of landslides, decrease aquifer recharge and groundwater availability, and further confine endangered birds into less habitat.

Figure 2.1: The Economics of Prevention (DLNR and Division of Forestry and Wildlife 2015)

If more money and resources were spent on prevention, the costs would be reduced for eradication in the long run, as fewer species would be able to establish large populations as Miconia has. Increased spending on prevention would not eliminate the need for eradication entirely but may be a huge reduction in total costs. The poisonous brown tree snake provides an example of the economics of prevention versus eradication. The brown tree snake is predicted to cost Hawaii at least $2.14 billion annually in damages, due to impairment to infrastructure (the snakes hang and crawl on electrical and telephone lines), health costs, and decreased tourism (DLNR & Division of Forestry and Wildlife, 2015). This estimate does not include the costs to the ecosystem, as the brown tree snake is extremely deadly for birds, or the conservation programs that would pop up to save the native birds. These numbers make invasive species management an extremely costly project, that may be an impossible battle given the current lack
of resources dedicated to these tasks. In 2015, the proposed and ultimately allocated budget for HISC was $6 million, which is a mere fraction of what is spent by non-profits and agency funds to cover ecosystem restoration. Just to eliminate the listed target species in the chart (LFA, Miconia, and Red Imported Fire Ant,) the state and other sources currently spend at least $1 billion annually to protect Hawaii, estimated by the Legislative Reference Bureau (Ikuma et al., 2002). This number may seem high but would triple should the brown tree snake establish a population in Hawaii. However, the governor has only approved a small fraction of this eradication sum each year, up to $6 million for fiscal year 2016-2017 from just $2 million in HISC’s first two years in 2005 and 2006 (DLNR & Division of Forestry and Wildlife, 2015). Therefore, the current effort of eradication is extremely underfunded, given how costly an effective effort would be. The state legislature would need step up the invasive species management budget annually to 100 times the current commitment to achieve results.

Also, all of the species that have sucked funds from the state budget are still found in large numbers in Hawaii, despite the millions spent each year. Miconia, introduced over 60 years ago, is found in such large populations in Maui and Oahu that scientists fear that the invasion is at a point of no return, adding to its reputation locally as the “green cancer” (DLNR & Division of Forestry and Wildlife, 2015). The plant was introduced to private nurseries, but its ability to outcompete other trees and produce between one and three million seeds per tree each year that remain viable for 15 years has ensured its dominance in the state (Ashe, 2017; MISC, 2017a). The state, after spending $672 million annually up until 2017, has virtually cut off funding for Miconia-related projects, as the possibility of a Miconia-free Hawaii seems impossible. Franny Kinslow Brewer, the communications director for the Big Island Invasive Species Committee (BIISC), succinctly explains the problem: “This is one of the scary things about working in

7 No updates budget allocations released publicly after FY 2016-2017.
invasive species: “the Legislature gets kind of fatigued…It gets more and more difficult to get funding for something year after year when there really isn’t an eradication…in sight. You’re then in a management and control scenario pretty much forever” (Ashe, 2017). Not only is the process of eradication seemingly futile, but the difficulty to fund the initiatives increases each year, as the progress is minimal at best.

The LFA has spread from the Big Island in 1999 to Kauai, Maui, and Oahu, impacting agriculture, tourism, schools, and nurseries. After it arrived, the state attempted to control it, but within three years, the LFA had spread to over 21 locations across the state (Lee, Motoki, Vanderwoude, Nakamoto, & Leung, 2014). The species has no known positive contributions to the island ecosystem, instead repeatedly stinging causing pet blindness, biting humans resulting in large itchy rashes, and biting endangered reptiles and birds (see Figure).

Figure 2.2: The Effects of LFA in Hawaii (HISC, 2015a)

Complete eradication is predicted to cost $6.8 billion and would take approximately 35 years (DLNR & Division of Forestry and Wildlife, 2015). The Hawaii Ant Lab (HAL) estimates that “the total eradication of ant from Hawaii Island [Big Island] is both not probable and would be extremely expensive, potentially costing over $1B annually” (DLNR & Division of Forestry and Wildlife, 2015). To remove the LFA from only the Big Island would cost more than the entire state budget and is likely not to succeed. Eradication appears to be a bad investment for the state and could be one of the reasons why appropriations for invasive species management were
less than two percent of the state budget in 2017 (Hawaii Department of Agriculture et al., 2016). However, prevention methods provide an alternative to invasive species management that is more cost-effective and feasible to prevent the arrival of invasive species in the first place (Figure #).

Figure 2.3: The Benefits of Prevention (Cornell Cooperative Extension, 2015)

The prevention of invasive species would require airports and other ports of entry to step up the quality and availability of inspection facilities, number of inspectors, technology used, and pre-border partnerships to handle imports. Simple changes at the border would prevent the establishment of most invasive species, reducing the costs needed for eradication, control and minimizing the area infested, as depicted on the left side of the chart. Additionally, until an effective system is in place at the border, the state continues to add new species from ships, planes, passengers, etc. It is not rational to work solely on eradication while new potentially invasive species arrive every 18 days on average (Ikuma et al., 2002). The cost of eradication, which could be billions given the cost of eradicating the brown tree snake alone, would be saved if prevention was improved. The estimated cost to improve Hawaii’s prevention infrastructure
and capacity is $50 million annually, which would require significantly less funds than the current spending of over $1 billion per year on eradication (DLNR & Division of Forestry and Wildlife, 2015). The Legislative Reference Bureau calculated “that approximately $57,488,910 in state, county, federal, and other funds was expended by various state, county, and federal agencies to fight invasive species in fiscal year 2013-2014… while less than $19,000,000 was spent on prevention and detection activities” (Rago and Sugano 2015, p. 172). The lack of emphasis on pre-border and border prevention tactics is a missed opportunity for the state to funds invasive species measures with the greatest returns.

*Biocontrol Alternative?*

Other inventive techniques to manage invasive species include biocontrols, where a species is intentionally introduced to consume and wipe out an invasive species without becoming an invasive species itself. The complicated nature of species interactions makes it difficult to use biocontrols as a method of invasive species eradication. The Rosy Wolf snail, which was brought in to eat the giant African snail, failed to do so and instead has become a predator to native endemic land snails. The invasive snails impact has driven many Hawaiian tree snails into extinction, including most recently *Achatinella apexfulva* in January of 2019 (Wilcox, 2019). Mongoose, introduced to remove rats, has also become an additional predator to native birds, amphibians, and plants. Therefore, it becomes very difficult to set up biological control agents to round up invasive species as the ways in which these species will interact in the host environment vary. Biocontrols are not a reliable method of invasive species management and should not be depended upon until other options have been exhausted.

Increased security at the border would help to control the distribution of invasive species, which may be contained in isolated populations and not evenly spread to all islands. Prevention also prevents the arrival of some of the most devastating species that Hawaii has not yet had to
pay for, such as the brown tree snake. An order of magnitude higher spent on prevention would significantly reduce Hawaii’s vulnerability to new species.
Chapter 3 Background and History: The Story of Invasive Species in HI

Brief Introduction

Invasive species are not an affliction only in Hawaii but have impacted the U.S. and all over the world for centuries. Famous invasive species in the U.S. include the European starling, the zebra mussels of the Great Lakes, the Asian carp which has overtaken American rivers, and the kudzu vine, which can be found climbing up homes, fences, and electrical poles alike, obscuring everything in a dense green copse. These aggressive species all have two things in common: their destructive characteristics which support their domination over new environments, and the improbable chance that these species will ever be removed. Hawaii also has also had several significant arrivals since the first Polynesians set foot on the beaches to the European expansion of trade and globalization over time.

Historical Introductions: The Beginning of Invasive Species in Hawaii

The Canoe Species: Native Hawaiian Impact on Island Biota

The Hawaiian Islands remained relatively untouched for millions of years, with the occasional sweepstakes dispersal of a seed or bird, until the arrival of the Polynesians. The rate of new species introduction was one species every 50,000 years compared to one species every 18 days in 2018 (Ewel et al., 1999; Martin, 2019). Prior to the influx of humans, Hawaii was characterized mainly by plants and had one native land mammal, the Hawaiian bat (Cox, 1999, p. 175). There were no mosquitoes, ants, or ungulates such as pigs and deer. The plants evolved to the landscape, as 89 percent of native plants are found nowhere else in the world (Cox, 1999, p. 176). Species radiation expanded the few colonist species that survived into thousands of descendent species of land birds, snails, and plants in an overwhelming display of island biodiversity.
The Polynesians that arrived in Hawaii two thousand years ago brought with them over 25 species of plants and several animals, including the Polynesian pig, rat, and dogs (Kahanu Garden Staff & National Tropical Botanical Garden Administration, 2017). Their arrival influenced the composition of species, as the native Hawaiians brought predators to the islands that had no native equivalent. The native birds were commonly flightless and inexperienced with mammals, which led to the extinction of 60 species of native birds shortly after Polynesian-arrival (Cox, 1999, 176). The Polynesians cleared the forests for agriculture, further causing the extinction of plants, invertebrates, and birds even prior to the first Europeans.

The plants and animals that the native Hawaiians brought were mainly for food and medicinal purposes and are generally less invasive. These herbs and trees required careful gardening and planting to build forests and crops, such as the cultivation of the lowland wetlands for kalo (taro) as a staple food in traditional diets (Kahanu Garden Staff & National Tropical Botanical Garden Administration, 2017). Many of the plants were low risk in terms of invasiveness and used for housing, instruments, weapons, and to treat a variety of ailments. Species that have become invasive today, such as rats and pigs, are hybrids with European species. The original Polynesian pigs and rats were smaller and could not inflict as much damage as the larger European varieties such as the wild boar and the Norwegian rat (Cox, 1999, p. 180). Although the Hawaiians did reduce the diversity of the avian population, the overall impact of the native species was small in comparison to the later arrival of the Europeans. The Europeans opened Hawaii to the rest of the world and expanded the cycles of biotic losses and extinction initiated by the first Hawaiians.

Phase 2: European Introductions

Captain Cook, credited with “discovering Hawaii”, landed in 1778 from England, increasing the rate at which invasive species reached Hawaii exponentially. Post-European
contact, new invasive species began to land in Hawaii at the rate of 25 species per year (Cox, 1999, p. 177). Hawaii became a bustling port and trading depot, due to its location connecting Asia, North America, and the South Pacific, and became a leader in many industries based on its abundance of natural resources.

One of the first industries to take off in Hawaii was the rise of whaling. The whaling industry collapsed after 1860, but not after bringing thousands of invasive species on the hulls of ships to Honolulu Harbor and the outer islands (Maclellan, 1997, p. 99). By 1822, 140 whaling ships arrived in Hawaii each year (Nagata, 1985, p. 37). Older ships carried dry ballast to stabilize the load from waves and storms, which was composed of soil, rock, sand, and held a variety of species that survived when discarded in Hawaii (Cox, 1999, p. 30). The whalers continued to introduce sources of meat, such as goats and pigs, to ensure that a hearty meal could be found on the next trip without regard to the ecological consequences. The whalers introduced avian malaria and other diseases which continue to threaten the bird stocks today (Nagata, 1985).

The rise of the sugar industry in Hawaii also contributed to the introduction of invasive species, including the famous mongoose problem. Between the 1860s and 1880s, Hawaii’s sugar plantations experienced a massive boom, transforming from small experimental crops to thousands of acres in sugar production each year (Maclellan, 1997, p. 98). The mongoose is a weasel-like animal from India that was brought to Hawaii in 1883 to stop the rats from eating the sugar cane (HISC, 2013c). However, the mongoose only minimally impacted rat populations, and added another predator to the onslaught on native birds, insects, and other animals. The mongoose is estimated to cause $50 million in damages to Hawaii and Puerto Rico annually, using 1999 figures (HISC, 2013c). The sugar industry, like whaling, brought people and species from all over the world to Hawaii, including workers from China, Japan, Portugal, and Puerto Rico to work in the fields and run the processing and export of sugar and pineapple.
In the late 1800s, Portuguese settlers brought the invasive firetree to Hawaii when they left Portugal to become the managers of the local sugar plantations. The tree was thought to be useful for erosion control, following the deforestation caused by the sandalwood trade, which prompted the Hawaii Department of Forestry to plant thousands of acres on all the main islands in the 1920s and 1930s (Cox, 1999, p.178). The species outcompetes native trees like the ohia because it has nitrogen-fixing roots which allow it to grow quickly, covering approximately 30,000 acres in Hawaii. After the European arrival in Hawaii, extinctions of endemic fauna and flora have become common place. 13 Hawaiian land birds, 500 land snails (50 percent of all known Hawaiian land snails), and 27 species of lepidopterans (butterflies and moths) have gone extinct (15 directly from the impacts of invasive species) since Europeans landed in Hawaii (Cox, 1999, p. 183).

As trade increased and Hawaii established a reputation as a port, so did the number of invasive species. Arrivals carried varying degrees of risk. The arrival of the Argentine ant in 1940 on Oahu, most likely as a stowaway on military vessels, led to the displacement of many native species (Cox, 1999, p. 183). When the ant reached Haleakala Crater in 1967, it threatened the 235 native insects endemic to Hawaii, including 83 species which are only found on the Haleakala volcano (Cox, 1999, p. 183). The loss of native insects also influenced the loss of native plants, as many of the insects are the primary pollinators. By 1998, 80-90 native plants were known or believed to have gone extinct, due to the extermination of insects and loss of habitat (Cox, 1999, p. 184). Cases like the Argentine ant began to raise the alarm bells in local naturalists’ and outdoor enthusiasts’ minds, as the landscape of Hawaii was transforming before their eyes.

The rise of mammals in Hawaii also highlighted the scope of invasive species infiltration. 18 species of wild or feral mammals can be found in Hawaii today, where the most detrimental
of these species are the wild pigs and goats (Cox, 1999, p. 180). The pigs and goats consume a wide variety of life for food and uproot the soil in the process. The pigs especially demolish plants and shrubs, forming loose top soil which contributes to erosion and increased water runoff. Goats arrived in 1778 and have since spread to almost all major islands. The problem received financial attention when goats entered national parks and the endangered plants and insects were threatened by the goat browsing (Figure #).

![Image](image.jpg)

Figure 3.1: Goats in Haleakala Crater (1963) Versus the Return in Native Vegetation (2012) (Yocom, 1967)

The goats were ultimately removed through extensive work done by the NPS to allow citizens to harvest the goat meat, hiring contractors to build fences at the cost of $3000-6000 per mile and maintaining the fence at all times (Yocom, 1967). At that point, Haleakala Crater and other mountainous areas had been stripped of vegetation, and iconic species such as the silversword were dwindling in populations due to overgrazing, prompting more resources to go to conservation and recovery. Internationally, the movement also began to take off, as scientific data began to illuminate the ways in which invasive species directly harm ecosystems, especially island communities.
In 1958, a book was published which began to change the public and policy perspective on invasive species around the world. Charles Elton, an English zoologist, was one of the first in his field to study community ecology and to examine the relationships between plants. He wrote the book *The Ecology of Invasions by Animals and Plants* to explore the effects of the spread of nonnative organisms on a recipient area caused both anthropogenically and naturally (Hardy, 2019). The book is still the most cited source in the field of invasion ecology (Richardson & Pyšek, 2008, p. 161). The book did not take off as a reference for invasive species studies until the 1990s, when scientists began to recognize the scale of the problem after the Scientific Committee on Problems of the Environment (SCOPE) program in the mid-1980s (Richardson & Pyšek, 2008, p. 163). The SCOPE program, run by the International Council of Scientific Unions, ended with a conference in 1984 where published studies on biological studies were brought into the limelight (Cox, 1999, p. 9). Elton’s visionary themes continue to be relevant to invasive species work today, focusing on the invasibility of islands and competition as a mechanism of invasion. His work began future efforts of the scientific community to study invasive species impacts on biodiversity, species dispersal, and resource availability, which picked up in the 1990s.

Historically, the public has been relatively on board and receptive to the fight against invasive species: reporting sightings, conducting community science, and volunteering to remove invasive species. In 1990, six rabbits were spotted in Haleakala National Park on Maui, prompting the start of an eradication program to trap the wild population (Ewel et al., 1999). If the population was not caught, in five years the rabbits could be 14 million strong (Cox, 1999, p. 175). Therefore, the NPS as well as local people became extremely concerned about other invasive species, especially ungulates and mammals, that could change Hawaii drastically.
However, there have been a few notable parties who are reluctant to remove specific invasive species, such as the hunting community and nurseries. The opposition to invasive species removal is targeted towards invasive species which have been established in Hawaii for generations and less towards future invasive species prevention efforts (although some nurseries do not want to be regulated strictly on imports of new plants). Fortunately, ranchers and farmers have become conscious of the controls they use to manage their yields (no more mongoose mishaps) and have worked to minimize the risk they pose to Hawaii’s biota.

**Hunting Communities’ Argument Against Invasive Species Removal**

Deer have an interesting legacy in Hawaii, which reveals the rare public outcry against the removal of an invasive species. In 1868, axis deer were introduced to Molokai as a gift to the Hawaiian monarch, King Kamehameha V (Associated Press, 2015; Kubota, 2011). Maui received axis deer in the 1950s as part of a veterans hunting program after World War II, when “biologists believed they could improve the environment by introducing species that didn’t naturally exist” (Kubota, 2011). The deer on Maui have caused over $1 million in damages annually to farmers, yet many locals feel that hunting the deer has become an important part of Hawaiian culture (Associated Press, 2015). The hunters complain that removing the deer would remove a form of subsistence for their families. Legal action occurred in the 1990s, where the Pele Defense Fund won a legal battle to ensure Native Hawaiian access to conservation and park lands to hunt the axis deer, which now are found on almost all inhabited Hawaiian islands (Associated Press, 2015). The hunting community is not opposed to preventing invasive species in general but is invested in the continuation of certain invasive species despite the harm the species cause to native ecosystems and local economic activity. One hunter even went so far as to have deer illegally transported to the Big Island via boat, where the deer swam ashore (Kubota, 2011). The Big Island is still approximately half native forest, a higher proportion than
any other island, and this forest is now threatened due to the growing predator-less deer population (Associated Press, 2015). Therefore, hunting groups in Hawaii need to understand the consequences of their actions and realize that before they introduce a species for sport, they need to examine the repercussions to the ecosystem and the stability of the system at large. Deer and sheep populations continue to spread across the land, consuming native plants and disturbing the soil, creating space for more invasive species to establish. Citizen education is crucial to a pest-free Hawaii, as the border inspection facilities and agents can only go so far as to keep out species like deer that seriously alter island ecology.

Nurseries Argument Against Invasive Species Removal

Many nurseries are concerned that regulations regarding invasive species would impact business and prevent the success of local companies. Nurseries are a known pathway of invasive species introductions, as many species hitchhike on non-invasive plants that are difficult to detect or prevent. Known highly invasive species, under the current black-list framework, are difficult to prevent, as the state is at the mercy of the national Noxious Weed list which focuses on keeping out species that harm U.S. crops and livestock. The plant Miconia was introduced by private nurseries in 1961 and rapidly proved to be incredibly invasive, dominant, and water-intensive (MISC, 2017b). However, the species was not placed on the federal list until 2008, so there were no limits to its importation and sale in the state for over 45 years (Webb, 2018). Miconia has become a widespread problem because the state did not have the administrative authority to regulate it and the federal policy only prohibited species that harms agriculture. Horticulturalists like the plant for its large purple velvet leaves but beyond its aesthetic qualities, the plant has no benefits to the economy, people, or nature. The Coordinating Group of Alien Plant Species (CGAPS) has tried to pass a state list of restricted plants which would prevent a future Miconia-like invasion. 38 high-risk species have been identified by CGAPS, but some are
used in landscaping and commercial sale, prompting an outcry from plant nurseries (Webb, 2018). Josh Atwood, Invasive Species Coordinator for the DLNR Department of Forestry and Wildlife (DOFAW), disclosed that as soon as the Hawaii Interagency Biosecurity Plan (HIBP) passed in 2016, “a coalition of nurseries sent a letter to express the impact of invasive species legislation on their business and that they don’t want the responsibility for control or eradication” (Atwood, 2019). Nurseries and horticultural programs need to understand the ecological implications of these imports, which often escape garden boundaries, and be charged for invasive introductions, such as the LFA and coqui frogs, that the plant sales have brought into the state. The threat of a fine may increase pre-border partnerships, where an importing garden works with a supplier to ensure that all potentially harmful species have been removed prior to shipment.

*Industries Causing Invasive Species Today*

Besides the nurseries serving as a primary pathway for invasive species introductions, the import and export of goods also continues the problems of invasive species from the days of whaling and sugar cane. Hawaii imports 90 percent of its food and 80 percent of all goods (Hawaii Department of Agriculture et al., 2016). The main exports from Hawaii only account for $598 million in business in 2013, less than 0.1 percent of the nation’s exports (Crescenzo, 2014). The lack of production within the state leaves the state vulnerable to outside fluctuations such as storms, that could prevent the transport of goods into Hawaii, leading to a complete lack of resources just a week after supplies are interrupted (Woody, 2015). The state also is dependent upon a flow of goods from other places to meet domestic need, opening Hawaii to more invasive species introductions. The largest exports from Hawaii also are mainly agriculture, meaning invasive species could further diminish this fledging market: shrimp and prawns ($18 million), coffee ($14 million), papaya ($9 million), and nuts and seeds ($4 million) (Crescenzo, 2014). The imports of agricultural products are a vector of many introductions that are wreaking havoc
on health and profits alike; the coffee borer arrived on imported coffee plants in 2010 and has virtually eliminated profits in the coffee industry, as almost all revenue goes back into invasive species control (Doria, 2018). Imports are also very expensive, amounting to a total cost of three billion a year, and only the inspection facility on Maui has the capability to open produce in a contained space. Any other produce or furniture shipment is inspected open-air, meaning whatever bugs and pests fly out when a box is opened are now introduced to Hawaii (Frostad, 2019; M. Loope, 2019). Local agriculture could help to reduce the reliance on imports and also decrease the rate of invasive species introductions.

Hawaii’s economy is at the mercy of the suppliers of its imports as to what species and diseases are brought overseas. The tide in Hawaii is generally towards invasive species prevention, which would protect most Hawaii businesses and interests, and is supported by the majority of the public. The international level of regulation also has helped the U.S. as a whole advance the techniques used to better manage this silent invasion. At the international level, Hawaii along with the U.S. as a whole is working to standardize invasive species procedures to ensure a global level of protection.

**International Policies Regarding the Prevention of Invasive Species**

Hawaii is influenced both directly and indirectly by the international community and laws over international waters. In September of 2016, the state hosted the International Union for the Conservation of Nature’s (IUCN) World Conservation Congress (WCC) (IUCN, 2017). The IUCN was founded in 1948 to brainstorm solutions to problems in the natural world and collectively change policy that better serves the planet’s interests. Hawaii policymakers, as demonstrated by their involved with the IUCN, are involved with the battle against invasive species at the global scale and partner with a variety of international mechanisms to achieve the same goals.
Direct International Policy Affecting Hawaii

Ballast Water Management Treaty 2004

Ballast water, the movement of species in the water used to stabilize ships, is regulated by the International Convention for the Control and Management of Ship’s Ballast Water and Sediments and was passed after 14 years of negotiations between member states (International Maritime Organization, 2019). The U.S. has been a member since 1950, so all ships must have a ballast water management plan which is approved by the International Maritime Organization. As ballast water treatment technologies improve, the group reconvened to attempt to adopt the uniform implementation of modern treatment by all member countries in 2008 (International Maritime Organization, 2019). A strengthened policy that has more guidelines for enforcement of ballast water treatment is needed, as Hawaii currently has two Coast Guard workers dedicated to ballast water (Martin, 2019). The workers “never test ballast water, never assessed if it’s still a risk” divulged Christy Martin, CGAPS Program Manager, and the threat is not well studied as to document how many species are introduced in this pathway each year (International Maritime Organization, 2019; Martin, 2019). CGAPS is working with the federal level EPA and Coast Guard to attempt to improve Hawaii’s standard for ballast water discharge and to protect marine life from invasive aquatic organisms, such as zebra mussels or cholera bacteria (Berkowitz, 2017; International Maritime Organization, 2019).

Indirect International Policy Affecting Hawaii

Many of the international policies and laws that mention invasive species do so indirectly and instead pay attention to the movement and spread of species across the planet as that relates to biodiversity and conservation, especially in regions which are home to iconic endangered species. The following list is a general overview of international laws that overlap with invasive species management.
Convention on Migratory Species (CMS) 1979

Convention on Migratory Species, otherwise known as the Bonn Convention, was formed on June 23, 1979 to attempt to conserve wild animals that cross international borders (Convention on Migratory Species, 2018). The United Nations Environmental Program backs the CMS and the U.S. has signed on to a variety of formal agreements and memorandums to protect animals that do not stay within arbitrary national boundaries. For example, humpback whales that migrate between polar feeding regions and Hawaii must be managed by international parties and any disagreement between them would impact the whale populations at all points in its life cycle. The CMS meets every four years but mainly provides guidelines that are up to participants to adopt and follow. The Convention on International Trade in Endangered Species of Wild Flora and Fauna operates in a similar fashion, with the mission to stop the trafficking of threatened or critically endangered species.

Convention on Biological Diversity (CBD) 1992

The CBD is a multilateral treaty adopted by over 191 parties in 1992 at the Rio Earth Summit, with all the UN states adopting it except for the U.S. (Dickie, 2016). The U.S. does send representatives to the CBD and provides funding to biodiversity protection, despite not formally signing the agreement. The adoption of the CBD in the U.S. would formalize the nation’s commitment to protecting the country’s biodiversity, including Hawaii, by preventing problems such as invasive species which increase rates of extinction and habitat loss.

The international treaties and policy agreements encourage the U.S. to protect its wildlife but does not provide the enforcement funding or local level direction necessary for invasive species management in Hawaii. To understand the situation of invasive species policy in Hawaii, it is important to examine the national commitment to invasive species.

History of Invasive Species Management Nationally
Historically, governmental officials and policymakers have reacted to invasive species once their presence has caused significant damage worthy of attention. The European starling had expanded to 200 million strong across North America by 2011, originating from just 60 individuals introduced in 1890 (Zielinski, 2011). What started as a wish to bring all species mentioned in Shakespeare to the United States by one individual transformed into a national danger to all native birds, whose populations plummeted. The tale of the European starling should have brought the issue of invasive species prevention to the forefront of U.S. environmentalism, but instead, policies for thousands of species introductions continued to be reactive and ineffective for over a century later. In 2019, the U.S. is estimated to spend $137 billion annually on invasive species damages, control, and eradication (Hawaii Department of Agriculture et al., 2016). Many of these funds are attempting to reverse years of invasion, where the species has grown to such populations that the complete reversal of these populations is infeasible. This section examines the national invasive species policies that impact Hawaii. Hawaii is often limited by the national position and laws in what it is enabling to enact and enforce at the state level.

Lacey Act 1900

One of the most influential laws affecting invasive species is the Lacey Act of 1900. The Lacey Act essentially prohibited the trafficking of wildlife, originally as a way to reduce the selling of bird bounty across state borders (Wisch, 2003). Beyond protecting wild birds, the law has been expanded to prevent the introduction of non-native birds and animals as well as to include all sorts of wild species, from amphibians to mollusks. The Act makes it a criminal felony to ship wildlife and a civil crime to ship wildlife without marking it, with fines from $10,000 to $20,000 (Wisch, 2003). The USFWS Office of Law Enforcement enforces the Lacey
Act which is able to accomplish a variety of goals: prohibits the importation and interstate movement of listed injurious species, monitors the import, export, transport, sale, receipt, acquisition, or purchase of any fish or wildlife, including regulated wildlife products, or plant possessed, transported, or sold in violation of any law, treaty, or regulation of the United States, oversees interstate or foreign commerce of any fish or wildlife taken, possessed, transported, or sold in violation of any law or regulation of any state or foreign law, or plants in violation of any law or regulation of any state (Hawaii Department of Agriculture et al., 2016).

The Lacey Act today is hard to operationalize at the state level, as what constitutes “injurious wildlife” varies by location, by agency definition, and by authority. A 2015 state Legislative Reference Bureau states that “…the Lacey Act needs to be amended, there also seems to be a lack of agreement as to exactly what wildlife should be covered by the Lacey Act, due to the different mandates and missions of various involved agencies” (Rago & Sugano, 2015). The discrepancies between the federal Lacey Act and state DLNR and HDOA arise in the definition of injurious wildlife, as the DOA will permit pet trade imports for individual possession of species that the DLNR may consider harmful. By one agency's understated assessment, which was echoed by a few others, the State needs to be more proactive in clarifying these points of contention and confusion (Rago & Sugano, 2015, p. 167).

Migratory Bird Treaty Act (MBTA) of 1918

In the U.S., common birds have declined by 50 to 80 percent and over 25 percent of U.S. birds face extinction, with many of these specimens from island ecosystems (Borrell, 2009). The MBTA prohibits the import and export of any migratory bird and is run by the U.S. Fish and Wildlife Service (USFWS) in partnership with Canada, Mexico, Japan, and Russia (U.S. Fish & Wildlife Service, 2018b). The MBTA affects invasive species as federal agencies, including the military, has to ensure that its practices do not increase harm for these birds.
Endangered Species Act (ESA) 1973

In a similar vein of conservation, the ESA passed in 1973 works to list endangered and threatened populations of species (OA US EPA, 2013). The USFWS works with the U.S. National Oceanic and Atmospheric Administration (NOAA)’s Fisheries Service to implement the ESA. The ESA is an example of the precautionary principle at work, where federal agencies must prove that their funds and actions do not jeopardize a listed species. If a species is not on the list, then federal agencies are not bound to take additional measures to protect its habitat or survival through policies like invasive species management.

National Invasive Species Council 1999

Executive Order 13112 signed by President Clinton in 1999 mandates that federal agencies do whatever possible to mitigate the actions that spread invasive species within the United States and elsewhere (National Invasive Species Information Center & USDA, 2004). The Executive Order created the National Invasive Species Council as an inter-agency board that coordinates invasive species efforts between departments, housed in the Department of the Interior. Federal agencies have not been effective at implementing this mandate. The order has not been strictly enforced to ensure agencies are doing their best to reduce harmful introductions and the National Invasive Species Council has a weak presence (Delach, 2016). The group released its first National Invasive Species Management Plan in 2001 but the report delineates guidelines and suggestions that are optionally implemented by each department, with minimal updates and changes in the most recent 2016 report. In many ways, HISC was modeled after the federal National Invasive Species Council but both suffer from the difficulty in resolving inter-agency conflicts and responding quickly to emergency situations.

U.S. Department of Agriculture (USDA)
The USDA concerns itself with invasive species only in relation to agricultural activities, similar to the mandate of HDOA at the state level. The issue with USDA’s Plant and Animal Health Inspection Service is that it does not work to reduce invasive species arrivals that may cause other damage beyond harm to livestock or crops. The agency does not concern itself with restricting the threat of species which may affect biodiversity, human health, or safety (Delach, 2016). This gap can be seen in the relationship between Hawaii and California. Since California produces more food than Hawaii, USDA is more concerned about protecting California from potential threats than protecting Hawaii from species in California or the rest of the continental U.S. (Frostad, 2019; M. Loope, 2019). At the airports in Hawaii, bags are only scanned when residents and travelers are flying from Hawaii to another city in the U.S., at which point the bags are run through an x-ray machine. When landing in Hawaii from the continental U.S., the bags are only inspected visually but not run through machines or fumigated thoroughly.

The Department of Homeland Security is also involved with border inspection of pests and pathogens but does not coordinate its efforts with USDA. The Department of Homeland Security runs the U.S. Customs and Border Protection (CBP) program. CBP is mainly concerned with the illegal trafficking of goods, not potential invasive species. The question remains if the Department of Homeland Security should be involved after all, as rarely are organisms introduced with the malicious intent of causing harm or creating panic (Delach, 2016). However, until USDA concerns itself with the trafficking of damaging goods outside of agriculture, other agencies continue to haphazardly work on invasive species issues as it connects to their mandates: Department of Commerce, Department of Defense, Department of the Interior, Department of Transportation (Rago & Sugano, 2015, p. 8).

**History of Invasive Species Management in Hawaii**

*HDOA as the Leader in Invasive Species Action*
HDOA has historically been the agency most involved in invasive species prevention. The HDOA’s Plant Quarantine Branch (PQ) has actually been in existence for over a century, founded by one of the last Hawaiian monarchs King David Kalākaua in 1888. Encouraged by the growing coffee industry, the king proclaimed that no new coffee plants would be allowed in Hawaii due to a fear of pests or disease accompanying these new arrivals (State of Hawaii PQ Branch, 2018). In 1905, 14 snakes were seized in Honolulu which also brought attention to dangerous non-native animals which can enter Hawaii (State of Hawaii PQ Branch, 2018). The Mediterranean fruit fly arrived in Hawaii in 1910, which stopped the export of avocados and other produce from the state (Hollyer, 2000). The risk of agricultural pests prompted the expansion of the HDOA during the 20th century, which now includes six divisions like the Plant Industry Division and the Animal Industry Division that control for invasive species (to understand these practices, Ch.5 Hawaii’s Invasive Species Policy goes into detail).

The Animal Quarantine (AQ) branch arose from a concern in 1912 over rabies, where no cases have been found in Hawaii. The disease became widespread in California and the threat it posed to Hawaii grew due to the amount of trade and travel of carnivorous animals between these locations (State of Hawaii Animal Industry Division, 2018). The program began as a 120-day quarantine to test for rabies in arriving dogs, which has been shortened today to five days or less due to increased effort on the behalf of the pet owners. Starting on June 30, 2003, pet owners could submit bloodwork and other tests to the AQ veterinary labs, where the animal could be generally cleared pre-arrival, at the expense of the pet owner (State of Hawaii Animal Industry Division, 2018). The HDOA handles inspection of agricultural products and livestock at the borders but does not formally inspect for invasive species that are dangerous to the natural

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8 An organization chart for the HDOA is Figure # in the Appendix, Figure 3.
environment but not to food crops. HDOA runs quarantine programs, state-level noxious weeds lists, and pest control as its primary programs.

*Forestry in Hawaii: A Distinctive Set-Up*

The U.S. Forest Service (USFS) created the Institute of Pacific Islands Forestry (IPIF) for Hawaii’s forests but has no national forest land in Hawaii. The IPIF works in the Hawaiian Islands as well as several locations in the greater Pacific Ocean such as Guam, the Northern Mariana Islands, and Palau. The federal group was founded in 1967 and mainly conducts research on biodiversity and ecosystem health along with other projects (USDA Forest Service, 2017). USFS along with the IPIF has worked extensively on Rapid Ohia Death (ROD) to be discussed more in Ch.4 Case Studies. At the state level, forests are managed by the DLNR DOFAW.

*DLNR & DAR Manage Marine Invasions*

The Hawaii Department of Land and Natural Resources (DLNR) regulates the transport of wildlife to ensure that Hawaii’s natural resources are protected. The DLNR is the administrative home of HISC and often funds its programs when the state budget does not provide HISC with a portion of the General Funds. The DLNR has two main mandates: prevent the transport of injurious wildlife, and regulate ballast water and biofouling to avoid the loss of aquatic organisms (HISC, 2013b). The DLNR has thousands of acres of natural area reserves to manage and leaves it up to the Coast Guard to handle aquatic invasions along with the Department of Aquatic Resources (DAR) (Martin, 2019).

*University of Hawaii Research Programs*

The University of Hawaii funds and runs many of the research efforts related to studying the impacts and risks of invasive species in Hawaii. The college houses the Pacific Cooperative Studies Unit (PCSU) which has 300 staff members for several key projects: CGAPS, Watershed
Partnerships, and the HAL (HISC, 2013b). All of these positions rely on grants from HISC. PCSU houses and assists the invasive species committees (ISCs) on each island. CGAPS is a voluntary partnership between state and federal agencies along with non-governmental actors which works to “close the gaps” on Hawaii’s prevention and eradication mechanisms (Burnett & Coffman, 2015).

The federal actions of the 1990s revealed that Hawaii was experiencing the highest rates of invasive species damages in the country and the hope was to create a group that could avoid the restrictions of specific agency mandates to study invasive species breaches at all levels of government (Burnett & Coffman, 2015). CGAPS formed in 1995 and meets quarterly to discusses barriers and solutions faced by agencies and non-profits (Martin, 2019). This organization provides a space for information sharing and can lobby politicians to support invasive species initiatives, as opposed to HISC which is restricted in this capacity. CGAPS and HISC often collaborate and have representatives from overlapping interests but HISC cannot advocate for positions outside of the official governmental stance while CGAPS, as a research division of UH, can (Atwood, 2019; Martin, 2019).

**State History of Invasive Species Committees and Funding**

**The Formation of HISC**

HISC was formed in 2003 under Governor Benjamin Cayetano and first awarded funds in 2005 (HISC, 2013a). HISC is housed within the DLNR for administrative purposes but is a cabinet-level body focused on setting the vision and policy goals for the corresponding agencies to carry out regarding invasive species removal and prevention. HISC developed the Hawaii Interagency Biosecurity Plan (HIBP) in 2016 but does not have the capacity to operationalize these objectives. Instead, HISC, which is itself composed of the leaders of each respective agency involved, relies upon the leaders and their representatives to act upon goals set in
meetings. The agencies that participate in HISC are the DLNR, HDOA, HDOH, DOT, Department of Business, Economic Development, and Tourism (DBEDT), and UH.

HISC has been met with several barriers to successful leadership. Primarily, the funding is not always guaranteed, especially to the various invasive species committees (ISCs) on each inhabited island: MISC, OISC, MoMISC, KISC, BIISC. The general funds, appropriated by the state legislature, were significantly cut following the Great Recession, plummeting the overall budget and forcing the DLNR to fill in the gaps with its own funding, as seen in Figure 3.2. The natural area reserves (NAR) that the DLNR manages to protect habitat and remove invasive species end up spending around 75 percent of the annual budget on invasive species prevention at the border (Rago & Sugano, 2015).

![Figure 3.2: NAR Funding From DLNR Filling Gaps in HISC Budget from 2005 to 2014](HISC, 2013a)
DLNR also used funds for the ISCs and other initiatives from the Legacy Land Conservation (LLC) Program in DLNR, but the result left significant gaps and abridged programs from a greatly reduced budget for 2010 to 2013. The NAR special funds are generated by a conveyance tax levied on property sales in Hawaii but are meant for enclosing and protecting NAR reserves from pests, hunters, and ungulates (HISC, 2013a). In 2015, HISC pressured the state legislature for permanent funding to HISC, which was granted in 2017.

For the ISCs, the issue with the year by year variations in funding lead to uncertainty on what goals the organization can accomplish and concerns over job security due to a wide range in funding. Island committees have to apply for funding each year for specific projects, which is why the groups usually pick only a couple target species to concentrate their efforts (HISC, 2013a; Strohecker, 2019). MISC, for example, has three staff members solely dedicated to project proposals and funding applications, with just eight total full-time staff dedicated to research, outreach, and management of field teams (Strohecker, 2019). The need to allocate staff towards securing funding takes away from funds that could be used on the ground: helicopter rides to spot invasive species from above in isolated areas, supplies for field crews like trucks and pesticides to stunt growth, and publications to improve public awareness via newspaper columns, blog posts, and social media. Applying for grants from HISC leaves the organization unsure of what the budget for the next year is, as these proposals are granted on a project by project basis. The applied for need requested by various groups was $12 million in FY 2018, while the funded projects totaled $4.75 million (see Figure 3.3). The difference between the need and the amount appropriated means that many initiatives are only partially able to implement the project; 50 percent of applicants received funding but only between 50 to 70 percent of the original request (State of Hawaii DLNR and Division of Forestry and Wildlife, 2017, p.7).
The future of invasive species funding is finally improving due to the 2017 Hawaii State Legislature’s decision to add $4.75 million appropriated for HISC to the base budget, meaning that HISC will receive funding each year but the amount will still vary (State of Hawaii DLNR and Division of Forestry and Wildlife, 2017). The dedicated funding will make it possible for HISC to attract talent, long-term employees, and promote the continuity of projects from year to year. The HISC is working to act as a stable organization that permanent works on invasive species management in Hawaii.

Chapter Timeline⁹

1 to 5.6 Million years ago – The Hawaiian Islands form, with Kauai as the oldest and the Big Island as the most recent.

400 A.D. – Polynesians introduce new species via their arrival in Hawaii in canoes.

1778 – Captain Cook lands in Kealakekua Bay on the Big Island, introduces goats to two islands:

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⁹ All dates and facts sourced from the following: Cox 1999; Delach 2016; History.com Editors 2019; Nagata 1985; World Population Review 2019.
Kauai and Niihau.

1800-1850 – Strawberry Guava introduced as a fruit, escapes cultivation, feral pig hybridizes with Polynesian pig, escapes into forests. Mass loss of native forests due to the planting of pine and other commercially valuable trees.

1868 – Axis deer introduced to Molokai as a gift to King Kamehameha V.

1883 – Mongoose introduced to eat rats in sugar cane plantations.

1888 – Hawaii’s Plant Quarantine Branch within the HDOA founded by King Kalākaua, firetree introduced by Portuguese immigrants.

1898 – Hawaii is annexed by the U.S.

1900 – Hawaii declared a U.S. territory; Lacey Act passes U.S. Congress.

1912 – Animal Industry Division of HDOA forms to prevent rabies in Hawaii.

1918 – Migratory Bird Treaty Act adopted by U.S. to protect transient bird populations.

1940 – Arrival of the Argentine Ant on Oahu.


1955 – Rosy Wolf Snail introduced to Hawaii by HDOA to control the giant African snail.


1959 – Hawaii added as the 50th state.

1961 – Miconia introduced to Hawaii by private nurseries to Maui and Oahu.

1963 – Goats widespread in mountains and fields of most major islands.


1979 – Bonn Convention to protect migratory species.

1984 – SCOPE Conference reveals scientific evidence of the harm of invasive species.

1990 – Rabbits found and eradicated in Haleakala National Park on Maui, citizens concerned.

1995 – CGAPS forms to coordinate agency efforts between the public and private spheres.


1998 – 80-90 Hawaiian plat species thought to be extinct.

1999 – Executive Order 13112 passed by President Clinton, National Invasive Species Council formed. Melastome Action Committee begins to remove Miconia on Maui.

2003 – HISC is formed by the Governor to begin state action on invasive species. ISCs form under UH.


2016 – IUCN World Conservation Congress held in Honolulu.
Ch. 4 Case Studies of Various Threats to Hawaii, Both Current & Potential

Introduction

Hawaii has already been exposed to thousands of invasive species, many of which have been naturalized, meaning they have established populations on the islands that are self-sustaining and unlikely to disappear any time soon. Humans are both threatened by invasive species and pose a threat to them. For example, tourists often attempt to touch the Hawaiian green sea turtles, which then experience large growths which can affect their ability to swim and fend off predators. The native nēnē bird, found only in Hawaii in alarmingly small populations, is now growing accustomed to human food, which can affect its diet and bring the bird in harm’s way in locations like roads. These encounters with nature only further heighten the need to protect endemic species from invasive species. It is unlikely that a policy to reduce tourists on the behalf of wildlife would pass in the legislature but perhaps it is more likely that an invasive species bill to educate tourists on their impact on endemic species would find support.

It is challenging to predict whether an invasive species will become naturalized or will it become a threat. As mentioned in Chapter 1, often times a species that is invasive in one location is invasive elsewhere, but this is not always the case. Simple botanical families cannot be used to determine which plants may pose a threat to endemic species. For example, both the endemic ohia and the invasive eucalyptus belong to the myrtaceae (or myrtle) family, but both plants have very different influences on the landscape, with the ohia tree positively influencing other species and eucalyptus negatively altering the soil. A selection of case studies on ROD, rat lungworm disease, and snakes will expose and reinforce the legacies of Hawaii’s past efforts and framework.

Land Threats: Rapid Ohia Death

Rapid Ohia Death (ROD) on the Big Island

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Rapid ohia death (ROD) is a new disease sweeping the Big Island of Hawaii and killing off the native ohia tree. ROD is greatly exacerbating the decline of the ohia because of forest clearing. The ohia has been drastically affected by not only the fungi but a host of other issues. The loss of habitat has played a role in the clearing of ohia forests, to make way for housing developments, cattle ranching, and other forms of agriculture. The current forests are restricted to the upper elevations, which are less attractive to developers and farmers, and have become the last outposts of native cloud forest (Meyer & Cowie, 2010). The tree is a keystone species and is able to grow in the harsh lava rock of geologically young soil. “If these forests go away they are never coming back the same way” asserts U.S. Forester J.B. Friday, as the trees are so old and slow-growing that they will not effectively compete with noxious weeds (Saving Ohia, 2018). “The average mortality rate [because of ROD] is 10 percent per year, which means we are not going to have many trees at all after about 10 years’ time” states Flint Hughes, a Research Ecologist with USFS Institute of Pacific Islands Forestry (IPIF). The culprit of this extensive damage? A new phenomenon called ROD, appropriately named as the trees rapidly wilt and die within a couple weeks.

ROD is caused by either of two non-native fungal pathogens, *Ceratocystis lukuohia* and *Ceratocystis huliohia*[^10]. The fungi colonize the tree and prevent the uptake of water, causing the trees to die from drought stress. The empty spaces left by the dead trees allow easy territory for invasive species to enter, further cementing the improbability of a regrowth of the damaged forest. HDOA and DLNR, once informed of the severity of the problem, placed a quarantine on ohia transport and restricted ohia from leaving the Big Island. Hawaii Volcanoes National Park alone receives two million visitors per year, many of whom go on to other islands and could

[^10]: *Ceratocystis lukuohia* means destroyer of ohia and *Ceratocystis huliohia* means changes the natural state of ohia.
spread the spores. Due to the frequency of interisland travel and the way the disease is spreading, it is safest to reduce all travel from the Big Island and the NPS has advised all visitors to check and scrub their shoes to avoid further spread of damage.

Ecologically, the new species are not equal in terms of their impact on the host species, the ohia tree. *C. lukuohia* causes significant damage and is the more harmful of the two because of its ability to choke off the water supply of the tree by inhabiting the xylem (U. H. News, 2018a). This species quickly robs the tree of its water supply, causing the tree to turn brown and completely wilt within a day or so. *C. huliohia* ultimately causes the tree to die over a longer time period, slowly occupying regional water routes beneath the bark of the tree, causing the tissue to wilt and die (U. H. News, 2018a). The loss of a tree may seem inconsequential in some environments, but not in Hawaii. The ohia tree plays a disproportionate role in its environment and in the functioning and existence of other species in the ecosystem. Native forests are comprised of over 80 percent ohia tree which collect rain due to their height (over 40 to 60 feet tall) and provide critical habitat for other native birds, insects, and plants (Uchida, Zhong, & Killgore, 2006).

How did ROD become a problem? The main hypothesis is that the fungi spread by beetle “frass,” the sawdust powder formed by invasive ambrosia beetles gnawing through a tree or plant (*Saving Ohia*, 2018). The powder, if blown by the wind onto an open wound on an ohia tree, can infest and enter the tree. Unfortunately, wounds in the trees are quite common due to interactions with other birds and insects. The beetles have been linked to the spread of one of the fungi, *C. lukuoahia*, which is the more harmful of the two. The beetle frass contains 17 percent viable spores, which can transmit the disease to healthy trees (U. H. News, 2018b). The beetle is not native to Hawaii and was not previously thought to be harmful. The ambrosia beetles, native to Brazil and now widespread and invasive in some regions of the continental United States, have
been found primarily on Oahu and the Big Island, which probably played a role in why the epidemic started on the Big Island (Cognato & Rubinoff, 2008).

The delay in the recognition of the harm to the ohia trees exemplifies how prevention capabilities need to be expanded to minimize damage from invasive species, even before they are recognized as threats. The need for a rapid response from science is often frustrated by the delayed funding and communication of policy. Scientific studies also take time, as scientists eliminate possible explanations and run trials to test new hypotheses. Many trees had been dying but local residents were unsure of the causes, especially in parts of the Big Island that were isolated from one another (Saving Ohia, 2018). For example, one infected area might be miles away from another infected host, limiting the ability to collaborate or understand the extent of the problem until the problem is large enough that these parties seek help. This lag time in communication and search for a solution puts more trees at risk. The lack of documentation also affected the scientists, who took from 2014 until 2018 to identify the fungal strands as two new invasive species (U. H. News, 2018a). Scientists and residents of Puna, Big Island, had to wait until scientists understood the interactions between the wood and the fungi before a solution could be proposed.

The forests have seen a large death toll: 50 percent of ohia trees on the Big Island have caught the contagion, spanning over 6,000 acres of forest (McAvoy, 2015). This percentage translates to thousands of affected trees, which is most likely an underestimate as a tree can be infected but not show symptoms for months (McAvoy, 2015). The map below shows the regions in Hawaii where ROD has been discovered in specimens. Unfortunately, the problem has now crossed to Kauai from the Big Island due to the spread of firewood and transport of ohia logs and soil.
Ohia also acts as a sponge, soaking up moisture from the air and attracting the rain to fall. The plant is able to replenish the watershed, helps to refill the water table, and assists in the availability of drinking water for agriculture and other commercial activities (Gutrich et al., 2005; McAvoy, 2015). The Hawaiian rainforest has been reduced to just 58 percent of its original land cover, which diminishes its ability to harvest water and foster biodiversity (Gutrich et al., 2005). The loss of forests is a loss in water, as the net evaporation over land declines and the warm wet air is pushed out to the ocean. The water no longer is cycled back to the land, leaving the resultant landscape arid and unaccommodating to forests once the feedback loop has been established (Makarieva & Gorshkov, 2010). Without the tree roots and native layers of species filling specialized niches, a lot of the water is not retained in the forests and instead runs off to the sea, creating erosion and harming coral reefs in a layer of debris and dirt. Not only is the loss of ohia trees degrading the landscape and impacting the water supply but is also further expedited by other diseases and invasive species. In 2005, scientists discovered rust disease on the trees, which cause the leaves to cripple and deform (Uchida et al., 2006). This disease is thought to have arrived from ornamental plants from South and Central America that had traces
of *Puccinia psidii* called guava rust. The rust disease kills off eucalyptus trees, invasive members of the myrtle family, but also kills ohia. Guava rust first appeared on Oahu but due to the frequent inter-island trade of wood and plants, it has since spread to all inhabited islands (LaRosa & Hauff, 2006). The reproductive capacity of both trees is significantly stunted by the growth of guava rust, as young plants and saplings are not able to develop normally. Currently, the genotype in Hawaii has only caused minimal damage on ohia found on less than 5 percent of trees in the wild and of these trees, on less than 5 percent of the leaf matter (L. Loope, 2010). However, the arrival of more contaminated myrtle species diversifies the genome, increasing the likelihood of a more harmful variety that might have a larger impact on the already dying ohia.

**Rescue Efforts**

Not all hope is lost for the exquisite ohia tree. This tree has a lucky combination of serving as a keystone species to the forest ecosystem and also holding cultural significance to the native Hawaiians. Not all plants have such a visual and crucial place in society, which may limit the ability to rally a sustained effort to save them. The state has placed a quarantine on all ohia products.

**Take-Aways**

The uncertainty of what a species will do should not be a reason to not act, as was the case with the ambrosia beetle. might want to error on the side of caution because of the lag time it takes science to catch up. In the lag time or research and policy, forests may be lost.

**Snakes in Guam**

*Could Hawaii be the Next Guam?*

Guam is a U.S. territory in the West Pacific and similar to Hawaii, is known for its beautiful white sand beaches, lush forests, and sparkling waters. The island, previously a Spanish colony, became a U.S. territory after the Spanish American war in 1898 and has become an
important outpost for the U.S. military due to its proximity to Asia (Ives, 2018). However, this military relationship has been detrimental to both the ecology and tourism of the island, as the traffic of military crafts has introduced a variety of invasive species from far away, including the brown tree snake. Many scientists, ecologists, hotels, and airlines are concerned about the arrival of snakes in Hawaii, which could easily occur from a shipment from Guam, as Hawaii also houses military bases and serves as an important stop for vessels crossing the Pacific (Burnett et al., 2008; DLNR, 2013; Hawaii Life, 2013). What happened in Guam and why should Hawaii pay attention?

The Brown tree snake, *Boiga irregularis*, may pose the largest single threat to Hawaii, estimated to incur $2.14 billion in economic damages per year if introduced (Hawaii Department of Agriculture et al., 2016). Hawaii has no native snakes, beyond the endemic Brahminy blind snake which is more of a glorified blind earthworm but technically a snake due to its forked tongue. The arrival of snakes would be devastating to Hawaii’s ecosystems, as many species are found nowhere else and do not have evolutionary defense mechanisms against snakes. Since snakes are not native to Hawaii, many birds lay their eggs on the ground, leaving them vulnerable to consumption by snakes, which can reduce the population dramatically. This is what happened in Guam.

Guam had no native snakes prior to the arrival of the brown tree snake post-World War II. The brown tree snake is native to northeastern Australia, Melanesia, and Eastern Indonesia and is thought to have arrived to Guam via military cargo during World War II from either the Solomon Islands or Papua New Guinea (Wildlife Services, 2011). The snakes can grow up to 10 feet long but generally stay between three to four feet in Guam (Wildlife Services, 2011). The snake hunts at night and remains coiled in dark locations such as treetops or rotted logs. The venom from the snake does not pose a large health risk to an adult human but can harm infants
through bites and constriction and is especially toxic to birds (Wildlife Services, 2011). As of 2011, Guam experienced some of the highest snake population densities ever recorded worldwide, with estimates of 20-40 snake found per acre (Wildlife Services, 2011).

*Bad Snakes: Cost of Paying for a Lack of Prevention*

Why does the brown tree snake cause enormous damage outside of its native ecosystem? The brown tree snake has no predators in Guam or Hawaii, which has allowed its populations to grow largely unchecked. The snake is between an r-selection and k-selection species, meaning it produces a moderate amount of offspring, matures quickly and are relatively long-lived. This is a dangerous combination as an invader. The known predators in its native Southeast Asia, the wild boars, larger snakes and lizards, and some birds of prey do not exist in large populations in Guam.

In Guam, the tree snakes are managed by a number of U.S. federal agencies and partnerships. The USFWS funds eradication and detection efforts at Guam airports, to minimize the likelihood of its transport to other U.S. Pacific territories (Hawaii Department of Agriculture et al., 2016). APHIS Wildlife Services (WS) program also works to prevent the spread of snakes by using Jack Russell terriers to detect snakes, and also to protect the economic and ecological resources within Guam (Hawaii Department of Agriculture et al., 2016; Wildlife Services, 2011). Cargo and other vessels are screen offshore before entering and exiting Guam to determine if snakes or other pests are on board, which significantly reduces the probability of a successful introduction.

*Why Should We Learn from Guam?*

Residents and visitors alike comment on the silent forest that persists across the island of Guam, which is about 31 times less land mass than the Hawaiian Islands. The arrival of snakes leads to the complete and total decimation of Guam’s bird population, which has been reduced to
just three species. Without the birds, the forest is changing dramatically in more ways than one may think. 10 of the island’s 12 native bird species have become extinct or disappeared since the arrival of the snake during World War II (Borrell, 2009). The birds, who have had no large predators or snakes, generally laid eggs on the ground, which contributed to the success of the snake. The loss of the birds has larger ecological implications, further illustrating the complexity of the ecosystem that people sometimes cannot hope to understand until it is lost. 60 to 70 percent of the tree species in Guam depend on birds to disperse seeds (Borrell, 2009). The tree seeds handled by birds were twice as likely to germinate on the forest floor than those that simply fall, and these bird-handled seeds germinate on average 10 days quicker, which increases the success of planting against rats or diseases (Borrell, 2009). Therefore, the full ecological implications of the brown tree snake could lead to massive extinction of birds and loss of forests, due to the lack of birds. The complexity of these ecological relationships begs the question of what other ecosystem functions would be lost if this situation were to transpire.

Prevention and Detection

Figure 4.3: Guam Airport Sighting of a Brown Tree Snake (Wildlife Services, 2011)
The snakes are easier to discover at night, where shining a flashlight on trees and bushes can reveal a snake since the scales are sparkle and reflect light as depicted in the image above (Wildlife Services, 2011). Interdiction programs to intercept brown tree snakes in Hawaii would likely be run by HDOA; this burden requires staff to receive snake training where agricultural inspectors are flown to Guam and to import four sterile male snakes for dog training to be able to detect snakes (Associated Press, 2018; Frostad, 2019). Past programs run in Hawaii by HDOA to remove snakes during inspection and quarantine ran from the 1990s until 2009, when the programs were cut due to a lack of funding (Associated Press, 2018). The program has since been restarted in 2016 and is operating today, but there is little known about the potential arrivals that could have occurred in the seven years between 2009 and 2016. The programs train dogs, such as Jack Russell terriers, to sniff out the snakes and inspect the aircraft, which is an effective way of detecting a snake. The snakes may crawl into the tire wells and storage areas of the plane, as accidental hitchhikers to new territory (Oahu Nature Tours, n.d.). The renewal of dog training using the four sterile snakes and continued training in Guam is a step forward but may not be enough to avoid ecological catastrophe.

In a recent study to determine the best method to remove and prevent the brown tree snakes, a collection of researchers commented that “[r]arely, however, have policy makers or economists integrated prevention and control for optimal intertemporal allocation of resources” (Burnett et al., 2008). It seems that how HDOA and the Plant and Animal Quarantine Divisions approach prevention in the upcoming years will seal the fate of if the brown tree snake establishes itself in Hawaii. The program should work to adopt many of the policies that Guam has implemented now, such as offshore screening of boats, to better prevent snakes from even approaching the border.
Should the brown tree snake establish a population in Hawaii, eradication will likely be infeasible. An U.S.G.S. worker in Guam removed just over 100 snakes in three years (Borrell, 2009).

Snakes in Hawaii?

Hawaii has no native snakes yet the arrival of snakes each year seems to increase the probability of complete snake infestation. The brown tree snake is not the most common snake intercepted at the border. Instead, snakes that are prevalent in the pet trade are often confiscated or found in Hawaii, either via the state Amnesty program or the 643-PEST hotline. The snakes are rarely intercepted at the border when entering Hawaii and instead often found only once they are loose in the wild, reported by residents or found by field teams. This issue is likely due to the inability for HDOA inspectors to inspect “non-agricultural” goods, including mail. From examining local news stories from the past 20 years, the most common snake introductions are boa constrictors and ball pythons which are generally kept as pets (Janssen, 2019).

Figure 4.4: Reports in Local News of Snake Sightings, 1989-2019 (Janssen, 2019)
These reports are likely a massive underestimate of the number of snakes in Hawaii, as the points on the map only indicate snakes that were spotted and reported publicly (Figure 4.4). Many other snakes have likely passed through border control as mail and escaped its owner, without making headlines. In 1999 the fine for bringing a snake to Hawaii was $200,000; in 2019, this fine has risen to $500,000 and up to three years in prison (Oahu Nature Tours, n.d.; State of Hawaii PQ Branch, 2019).

*Marine R-Selection Species that Pose a Risk*

The ocean provides many of the recreational activities in Hawaii such as surfing but also is home to a diverse and colorful reef filled to the brim with irreplaceable fish, coral, and other wildlife. Many invasive species pose a threat to the fragile reef ecosystems, such as the lionfish, whose aggressive year-round breeding and role as the top of the food chain have led to its domination over warm waters in the U.S. Southeast and the Caribbean. As a native to tropical waters, the lionfish in Hawaii would probably thrive, posing a large menace to native species and humans alike due to their toxic spines (National Oceanic and Atmospheric Administration, 2019).

*Take-Away*

Hawaii’s prevention technology and capacity needs to be expanded to be able to detect every snake, or lionfish, that approaches its borders. Eradication may be infeasible for such species.

*Rat Lungworm Disease: A Never-Ending Threat*

*What is Rat Lungworm Disease?*

Rat lungworm disease is a neurological condition caused by contact with contaminated food that affects the spinal cord and brain, sometimes leading to death. The disease is attributed to two main vectors, rats and snails, which carry the worm between hosts. Rats transmit the
worm in larvae form until they release feces, which contain juvenile specimens. The juvenile worms are then consumed by snails who consume rats’ feces, who spread the worms to produce such as lettuce and kale. However, very few worms occur in the slime (Honolulu Civil Beat, 2017). When rats eat infested snails, the worms travel to the brain of the rat and then the pulmonary artery, where they mature to the adult stage and lay eggs. Once hatched, the eggs migrate to the windpipe and then travel through the digestive track back out of the rat through its feces, repeating the cycle (Honolulu Civil Beat, 2017). Ingestion is the primary way of receiving the disease in humans via a little snail or slug, where newly hatched gastropods may be smaller than a quarter of an inch long and difficult to see. The worm has two hosts\(^\text{11}\), the gastropods and the rats, and both are invasive to many regions across the Pacific, including Hawaii.

The worm is a particular parasite called *Angiostrongylus cantonensis* (*A. cantonensis*). Angiostrongyliasis or commonly known as rat lungworm disease, kills a number of people in Hawaii each year by affecting their spinal cord and brain. The parasitic roundworm can cause symptoms such as stiff necks and headaches on the mild end of the spectrum and neurological problems, severe pain, disability and death toward the extreme end (Ige & Anderson, 2019). Eosinophilic meningitis, which impacts neurological functioning, not only can impact humans but also mammals and birds (Kim, Hayes, Yeung, & Cowie, 2014). UH Mānoa conducted a study in 2018 which tested 200 sites throughout the Hawaiian Islands for the presence of rat lungworm disease in various species of snail and slug. The disease was found on five out of the six main inhabited islands, as visualized in the graph below.

\(^{11}\) For more information on how snails and rats spread the disease, see the diagram in the Appendix, Figure 4.
Several key trends arose from the data. More cases of infected specimens seemed to occur in areas on the windward\textsuperscript{12} side in warmer and wetter conditions (Grabowski, 2018).

Why are the infestations generally in the wetter and warmer areas and why does this matter? The parasite is commonly found in Southeast Asia, where the majority of cases globally have occurred. Due to the travel of rats and people outside of this region, the parasite has spread to every continent except Europe and Antarctica (Kim et al., 2014). The climate in Southeast Asia is similar to Hawaii: tropical and sub-tropical humid ecosystems with mild winters. This similarity has allowed rat lungworm to establish itself in Hawaii. The warmer and wetter areas also seem to have a higher occurrence of infected specimens, suggesting that residents in these regions may be more at risk than residents in drier leeward conditions. The genus \textit{Rattus} has

\footnote{\textsuperscript{12} The windward side of the island refers to the northeast side, which in Hawaii receives the most rain as the trade winds often blow from the northeast to the southwest.}
bene identified as the primary hosts of the parasite, which includes the Polynesian rat (introduced by the Polynesians to Hawaii), the Norway or brown rat, and the roof rat or black rat which are commonly found throughout Hawaii (Myers et al., 2019). On the windward side of the islands, rats are able to breed year-round as there is an abundance of plants and life to consume, from bird eggs to insects to crops (Tobin, 2005).

Implications of this case study show that research is crucial partner in preventing invasive species and needs to be formally integrated in the HIBP. Currently, no treatment plan exists that rids a victim of the parasite and the Disease Outbreak Control Division of the DOH warns against anti-parasitic drugs which can worsen the body’s response to the dying worms (Hawaii Department of Health, 2018b). Instead, the patient must wait for parasites to die, while suffering symptoms such as partial paralysis, tingling sensation in limbs, stiff neck, vision loss, and severe headaches (Hawaii Department of Health, 2018b). More research and funding need to be done to determine better methods of treatment and to involve the public more in the campaign against rat lungworm disease.

A public awareness campaign also would encourage citizens to eradicate invasive species that would harm their health, such as rats and snails, in their own homes and be more willing to pay for prevention policies. Home eradication of rats and snails can be costly, involving rat traps, poison that can damage other species through ingestion, and snail traps which also in and of themselves can pose a risk to small children or pets (Hawaii Department of Health, 2018a). Therefore, homeowners and residents may be cognizant through this process of the importance of prevention and the discounting of future costs that a preventative tax would seem more attractive and garner more support (Environmental Protection Agency, 2010).

Prevention has been aimed at washing produce thoroughly with tap water to make sure produce does not have snails on it, which are translucent. The flow of the water pushes the snails
off produce, so no chemicals are needed to treat the food. To reduce the population, citizens would kill the snails by putting out slug or snail bait, which can be toxic to animals like pet, or beer, which attracts the snails and can cause them to drown (Honolulu Civil Beat, 2017).

The issue with this disease is that both snails and rats are invasive and very well established; since they are already established, they are difficult to eradicate. The species that carry that infective larvae include both native, invasive, and non-native snails, but the primary carrier is likely to be Parmarion martensi (p. martensi). P. martensi specimens contained a. cantonensis in approximately 70 percent of samples, compared to the second highest species vector of Laevicaulis alte at 27 percent (Kim et al., 2014). The risks are manageable, with the number of infected cases in humans under a dozen a year. It would be unrealistic and beyond expensive to begin an eradication project on snails and rats.

Ecological Implications

Rats have prevented the restoration of native Hawaiian forests due to their ability to decimate plants by consuming seeds, flowers, and individual parts. Two species that used to exist in abundance, the lowland loulu palm and the coastal kanaloa plant, have been reduced to a single isolated rat-free location and disappeared from all other sites (“Remove Rats Restore Hawaii | Impacts of Rodents & Mongooses,” n.d.). The arrival of rats in Hawaii coincided with the loss of many of these plants in the pollen and soil records.

Agriculture Implications

Agriculturally, the removal of rats and snails due to the threat of rat lungworm disease would also improve crop yields. Up to 70 percent of a rat’s diet comes from sugarcane in Hawaii, which was a major cash crop until the last mill closed throughout the state on Maui in 2016. The Norway rat is the most harmful to sugarcane, but Polynesian rats can also cause significant damage to growing stalks as well as to surrounding crops of corn, pineapple and root
crops. Sugarcane is the only crop of economic prestige to be significantly threatened by Polynesian rats, which may have led to its ultimate failure as an enduring crop in the 21st century (Tobin, 2005). All three types of rats are difficult and costly to eradicate, as shooting and trapping requires many hours of paid labor, often with no measurable change. For example, sugar cane plantation workers trapped over 141,000 rats each year in the early 1900s but the crops continued to receive bite marks and tissue destruction with no discernable change (Tobin, 2005). The rats are estimated to cause between $6 and $20 million in damages annually, depending on the price of sugar and amount of pesticide used to reduce damage (Tobin, 2005).

**Take-Aways**

Rat lungworm disease demonstrates the potential risk of staffing a less functional DOH due to budget cuts post 2008-2009 recession. To diagnose a case, health officials need to understand the patient’s food history, such as where the food was sourced, where the person works, and when the patient became infected (Ige & Anderson, 2019). The DOH generally knows very little about how the patients become infected and is positing that the snails were ingested based on laboratory experiments conducted by UH research labs. The lack of staff and funding contributes to the delay in information, as investigations into recent deaths in East Hawaii and the Puna District are still ongoing and unsolved (Ige & Anderson, 2019). Rats and snails do cause damage in Hawaii, but these impacts have been managed by various agencies. Therefore, not all invasive species should be treated as the same level of risk, which would lead to an inefficient allocation of resources.

**Success Stories: How Much it Costs Compared to Prevention**

The tale of invasive species in Hawaii is not all doom and gloom, despite the overwhelming majority of invasive species yet to be maintained and eliminated. In Kaneohe Bay, a region once characterized by an invasive algae from a science experiment gone wrong,
the introduction of native Hawaiian collector urchins in large quantities eliminated the algae population by approximately 85 percent (DNLR: Division of Aquatic Resources, 2013; Heber, 2018). The eradication of veiled chameleons is another success story. Veiled chameleons were discovered on Maui in 2002, which led to a team of researchers from UH and MISC removing all individuals in a few years by continual study and communal reporting on the animals (MISC, 2007).

The labor-intensive nature of the removal of both of these species speaks to the need to focus resources on prevention, which is the cheapest option in preventing invasive species damage. To remove the algae, crews of researchers and workers picked algae by hand and rolled it on to boats, where it was then transported to shore and disposed of at local dump sites (Heber, 2018). For the chameleons, the MISC team tagged and used radio telemetry to track chameleons at all hours, finding each of the roughly 200 chameleons individually (MISC, 2007). The resources spent on the removal of these few dangerous individuals could have been less costly if done at ports of entry, where a simple screening or inspection could have confiscated the species before a population erupted.

Another success was the implementation of the 643-PEST hotline number, which has helped to catch and stop invasions before they have begun. A Hawaii Air National Guardsmen spotted a two-foot long lizard with a black tongue running across the pavement of the Joint Base Pearl Harbor-Hickam (JBPHH). Using the hotline, the monitor lizard was reported and apprehended, which prevented the introduction of a highly invasive species to the islands (HISC, 2015b).
Kauai and Lanai both remain mongoose\textsuperscript{13} free, as all the other inhabited islands have been exposed to these weasel-like animals. Major populations of coconut rhinoceros beetle, a highly invasive species, have been removed and destroyed, demonstrating the power of involvement with USDA (HISC, 2015b). The emergency response team of USDA APHIS, HDOA, and JBPHH has spent over 90,000 hours checking traps, collecting infested areas, and treating breeding sites.

All of these success stories expended huge sums of money to eradicate or control selected populations. The funds, if spent on prevention, would remove the need for such costly eradication measures. However, for emergencies, it would be advantageous to have funds that could be quickly allocated to catch a species early.

\footnotesize\textsuperscript{13} Mongoose were introduced in 1883 to actually reduce the rat populations; a misinformed measure as rats are nocturnal and mongoose are diurnal. Instead, the introduction had the opposite effect and increased the assault on ground nesting birds like the Hawaiian goose, nēnē, while failing to control rat populations (Tobin, 2005).
Ch. 5 Hawaii’s Invasive Species Policy Framework

Why have Hawaii’s Policies Failed?

The past system of invasive species prevention, education, and management has failed for several reasons. Primarily, the system itself is not able to actively inspect every good entering Hawaii, be it passenger baggage or cargo shipments, which leaves a lot of unknowns as to what is actually passing by the inspectors. The lack of staff dedicated to the project has been cited numerous times as a major barrier to prevention, with just 12 full-time inspectors on Maui (Frostad, 2019; Hawaii Department of Agriculture et al., 2016; K. Kawaoka et al., 2017; Plant Quarantine Branch, 2002). Staffing will most likely continue to be an issue as many pathways exist through which invasive species can enter Hawaii: commercial flights, air cargo, ship cargo, mail, private jets and yachts, and agricultural goods to name a few (see Figure below). To be able to fully inspect each pathway will be a multi-year goal, as outlined by the HIBP.
The current system relies on self-reporting, or the “declaration” of goods, that often fails for a number of reasons. Many people are not aware of the invasiveness of certain imports or the harm they could inflict in Hawaii that may be different from their home state (a pet alligator released into the wild in Florida is not as big of a deal as an illegal pet alligator released into the wild in Hawaii). Also, the system relies on the coordination and communication between many agencies: USDA, USFWS, Customs, HDOA, and the U.S. Postal Service (see Appendix). If the arrival is marine cargo, then DLNR and DAR are brought into the effort. Different agencies have various priorities; HDOA works to protect Hawaii’s agriculture from any threats and USDA attempts to prevent U.S. agriculture from any pests, but the actual threats they may have each identified to not always align. These discrepancies create gaps through which invasive species may enter the state, making the border as it is in 2019, relatively weak. Additionally, the forms mainly collect data for the HTA and are not processed in a timely manner, as the forms are shipped to Oahu to be examined. If a traveler did report possessing a pest, the state would not be likely to follow up until after the visitor has already left (Frostad, 2019).

*Citizen Pathways: How People Can Learn to Stop Packing Invasive Species*

Passengers pose a significant threat unintentionally due to the lack of education and strict enforcement of Hawaii’s policies. Every commercial flight poses a risk to the environment not only because of what specimens may be attached to the plane but also because of what passengers choose to bring. Items such as oranges from Florida could derail Hawaii’s citrus industry, introducing new diseases and pathogens that previously were not known to occur.

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14 An image of the self-declaration forms passed out to passengers on flights to Hawaii is included in the Appendix, Figures 5 and 6.
Passengers, if informed of the costs of their decisions, might make smarter choices and help Hawaii to protect its borders instead of serving as conduits of invasive species transmissions. The current policies function as a part of HDOA, with supporting help from DLNR, HDOH, HDOT, and other state agencies. The federal level, in this case USDA, is not meant to focus on the harm to an individual state but instead threats to the country at large (the USDA’s role will be discussed at length in a later section). However, if these groups joined efforts to educate the public, all would benefit. In the past, HDOA required all airlines to play a short video warning travelers about the risk of invasive species and asking for cooperation, prior to passing out declaration forms where people could declare if they were carrying any potentially threatening items (Frostad, 2019; M. Loope, 2019). The inspectors stopped showing the film with the rise of personal technology, as they did not feel the film was effective at changing behavior (Atwood, 2019; Frostad, 2019; M. Loope, 2019). The state has since relied on independent groups, such as MISC and the Nature Conservancy, to post materials and run public outreach campaigns (Strohecker, 2019). The result is the occasional poster by baggage claim or at a terminal, but no organized consistent campaign has been formed.

USDA has free and downloadable posters as a part of its “Hungry Pests” campaign to scare citizens with the potential consequences of invasive species. Many of the posters are a version of Figure 5.2.
These posters are not clear in terms of how invasive species will impact your community, merely creating a monster from a variety of invasive species and implying that the monster will eat crops. A more specific state-run campaign with local case studies is likely to better influence the behavior and consciousness of residents, as it would highlight the dangers to their specific community. Florida, Minnesota, California, and New York all have outreach and educational materials, including videos, online to educate the public. Public service announcements have also proven to be an effective way to reach the public and increase participation in reporting and interception of invasive species (Florida Department of Agriculture and Consumer Services, 2019). If Hawaii could increase outreach via television time or theater screenings of short invasive species videos, the public would serve as a better partner in protecting the islands from invasive species.
Other perhaps more creative ways could get the people interested in preventing invasive species by providing financial incentives for doing so. A proposed bill, HB20 “Relating to Taxation”, would provide residents with tax credits for trimming or removing the invasive albizia tree “under certain conditions” and HB29 establishes an income tax credit for removing albizia trees (State of Hawaii DLNR and Division of Forestry and Wildlife, 2017, p. 22-23). A similar tool could be applied to major importers or grocers who work to prevent invasive species in their cargo. A tax credit could be granted for a year of pest-free imports, or for building and operating a pre-border inspection team/facility prior to shipping items to Hawaii. Import substitution, where economic policies encourage the local production of a good to eliminate the need to import it, would also lower the rate of introductions of invasive species. Import substitution programs have been referenced as a possible way to reduce inter-island spread of species and support local farms and nurseries, proving that business and invasive species management are not always diametrically opposed (State of Hawaii DLNR & Division of Forestry and Wildlife, 2015; State of Hawaii DLNR and Division of Forestry and Wildlife, 2017). HB1325 passed in 2017 which includes appropriations to begin import substitution for high risk crops, but the exact program will not be implemented until 2020. The program may be a small incentive for farmers to expand their yields but is not the most direct approach to reducing the spread of invasive species.

Alternatively, some proposed bills would punish citizens for introducing an invasive species financially. HB1031 “Relating to Invasive Species” would require any person or entity determined by the HDOA to have introduced an invasive species will be financially liable for the eradication of that species (State of Hawaii DLNR and Division of Forestry and Wildlife, 2017, p. 22). Such a program would be difficult to implement, as many introductions are not intentional, and the vector is unaware of the presence of an organism in baggage or clothing. At
the business scale, increased fines could be inflicted by HDOA for quarantine costs but the loss to the business is usually already felt due to the delay in getting the goods to market as many goods are perishable (Frostad, 2019). Therefore, a positive incentive may be more likely to pass and achieve the desired changes in behavior.

*Plant and Animal Declaration Forms*

The concept behind self-declaration forms seems to be twofold: to educate tourists and locals alike about the risk of invasive species, and to prevent the accidental introduction of a new species not known to occur in Hawaii. The form does not effectively do either, as many alien species pass through undeclared. In the blitz inspections of Kahului Airport between September 2000 and July 2001, passengers declared on entry forms just 508 items out of 1,747 agricultural items later extracted by dog teams (Plant Quarantine Branch, 2002). The Plant and Animal Declaration forms therefore failed to encourage the announcement of 71 percent of agricultural goods (1,239 items) that could have harmful pests entering Maui (Plant Quarantine Branch, 2002).

The forms are a primary objective of the HTA, which uses the data on where tourists stay, for how long, and their reason for travel, with HDOA using their format to ask their own questions. Each flight and airline vary in how they present the forms, which are often passed out without pens and to family groups versus individuals, which limits the ability to confiscate every potentially pest-carrying object, like an apple or a Florida orange. The flight crews receive no training for the forms and some crews forget to collect them, making an inspector’s job more challenging when they meet the plane (Frostad, 2019).

The forms are intercepted by a PQ inspector at the jet bridge once the plane has landed, and the next sequence of events occurs very rapidly. Ideally, the inspector meets the plane, collects the forms from the flight crew, and begins to scan the forms as well as inspect
passengers as they deplane. The inspector cannot check every personal item or purse that comes off the plane and must rely on their vision only to confiscate anything if out in the open. The inspector is also gathering any forms that might not have been collected by the flight crews and skimming through the forms to see if any agricultural goods have been declared (Frostad, 2019). If any have been declared, then they might contact those passengers or try to locate them as they deplane, depending on the risk associated with the item. An inspector is assigned to each flight that lands, but often the inspector may be running late or caught up inspecting air cargo (Plant Quarantine Branch, 2002). If the passengers are gone by the time the inspector reviewed the forms, the inspector must rely on his or her ability to inspect the baggage as it is loaded off the plane. As the passengers head to baggage claim, the inspector races over to the baggage conveyor belt, to catch the bags before they are loaded on to the baggage claim carousel.

At the baggage off-loading point, the inspector watches as cargo staff unload the bags on to the conveyor belt, looking for primarily coolers and dirt (Frostad, 2019). Coolers, especially on inter-island flights, may have seafood and fresh produce in them, which is can be a vector of disease, bacteria, and pests. Dirt is also critical, as many microbes in the soil spread bacteria that harm plants between regions where no impairment previously existed (see ROD, Ch. 4 Case Studies). Any boots, work shoes, or hiking shoes with dirt maybe confiscated and cleaned if the inspector is able to find it. A bag may only be opened if baggage employees are present and if the inspector has reasonable belief that the bag poses a threat, which is entirely judged by the outside status of the bag. Once opened, an inspector places a small tag inside that shares with the owners that their bags were inspected and then places the bag back on its track to the baggage claim (Frostad, 2019).

John Frostad, an HDOA PQ inspector, shared many significant issues about this process. The inspectors often are swamped by the sheer volume of flights each day such that they do not
have time to go through each bag, carefully read every declaration form, or investigate each passenger’s personal items to be sure it is pest-free. The inspectors send the forms over to Oahu to be processed there by the HTA, who will go through the forms at length to again check for any declared goods. However, due to the high number of full capacity flights with each passenger group filling out a form, the staff at Honolulu may not process the forms for several weeks (Frostad, 2019). By the time a red flag is discovered, the tourists may be back in their home state, with an introduced species already brought to Hawaii. The “piece of paper is also outdated” Frostad says, as people do not always have a pen or do not take it seriously. HDOA used to have an informational video, but since personal technology has grown, they found it ineffective to present and limited in its impact on changing behavior.

*Agricultural Inspection Machines*

USDA runs agricultural inspections for flights to the continental U.S. and abroad but does not run inspections for inter-island travel. The machines used to reveal if a passenger is transporting produce, soil, live snails or other restricted or prohibited goods out of Hawaii. The machines are simple x-ray machines and are unable to detect anything at the microbial level. The cabinet x-rays, those which inspect baggage and cargo, are generally programmed to differentiate between scanned items like metals and liquids using various colors, which help to expedite the scan and avoid the need to manually checking each bag (Astrophysics, Inc., 2017). The x-ray machines should be followed up with an in-depth search if the bag contains suspicious goods. However, many inspectors simply wave passengers through, as the line builds quickly and there is no time to actually pull aside any bags that look risky. The lack of dedication on the part of the staff may be a matter of poor wages, a misunderstanding of the importance of the job, and or inappropriate training to spot invasive species. Christy Martin, Program Manager of CGAPS, shared that one of her highest priorities out of the 147 points made in the HIBP for 2017-2027 is
“to transitioning the HDOA to a 21st century department. The agency needs to move the import risk assessment to an electronic [system], submit lists of content within containers and flights so software assigns risks” (Martin, 2019). Martin also exclaimed how the agency does not use modern diagnostics to identify species, but simply “shows up and looks” at imports (Martin, 2019). The methods of identification are not sufficient to find and prevent viruses or pathogens, and the lack of dogs limits HDOA’s ability to find snakes and produce that may have been undetected or not subject to a scan. This facet of the border process to screen out invasive species needs to be significantly updated, as the modern technology exists to be able to identify species rapidly and efficiently beyond what the naked eye can see. An electronic system would also enable the state to log what it finds in baggage and cargo and begin to build a database of the risks and common species entering Hawaii. No such publicly available data has been collected in Hawaii since the 2002 Kahului blitz inspections. This database would assist inspectors in identifying patterns and repeat offenders, be they companies or geographic regions, that should be given more resources and paid closer attention to.

*Plant Quarantine Inspection Facilities*

The state currently has five to eight inspection facilities in the following locations: Kahului Airport, Hilo Airport (opened in 2016), Honolulu International Airport, and its satellite facilities. Hawaii is attempting a New Zealand-based pilot program of decentralized inspection facilities, called transitional facilities with a pilot-program of three transitional facilities not at ports (USDA & FSIS Oahu Department, 2018, p.15). This program is currently offsetting the lack of state-run alien species inspection facilities (ASIFs) but should only be seen a placeholder program while the state constructs its own ASIFs, since the exact quality and consistency of inspection is difficult to enforce at these off-port sites. An action item in the HIBP for 2017-2027

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15 More on transitional facilities and New Zealand’s approach to invasive species in Ch. 6.
requested the construction of new facilities and the request was passed in the form of HB 1325 “Relating to Biosecurity” in 2017, which requires “the HDOA to establish parameters and construction requirements for biosecurity facilities that provide for and ensure the safety of agricultural and food commodities” (State of Hawaii DLNR and Division of Forestry and Wildlife, 2017, p.22). Although the new facilities do not explicitly mention ecological impacts or non-agricultural inspections, future changes to the organizational structure of HISC could warrant the facilities to inspect all goods and cargo related to invasive species independent of agriculture.

*Animal Quarantine Inspection Procedures*

Amnesty Program: Illegal Introductions

If a person has managed, either purposefully or by accident, to get an illegal animal through border control, the HDOA has set up both an amnesty program and a permit system. The goal of the program is promote the collection of illegal animals by allowing people to voluntarily bring these animals to PQ facilities and local humane societies without punishment (Frostad, 2019; State of Hawaii PQ Branch, 2018). This program has been mildly successful in that people have used amnesty boxes to drop off unwanted illegal pets but the logistics for PQ is much more difficult. On Oahu, a snake was deposited in a box and officials did not know of its presence for several weeks, finally surprising the inspector who went to check out the situation (Frostad, 2019). The animals are not euthanized according to the HDOA website, but it is unclear what is done with them once intercepted or collected.\(^{16}\) Often times, it is very difficult to “ship the animal back” especially for larger predators, birds, or reptiles. According to PQ inspectors, non-

\(^{16}\) The website says that the officials do not practice euthanasia but the inspectors I interviewed said they do. The issue for the inspectors is many animal rights activists do not approve of the deaths of these accidental arrival animals, yet the inspectors are constricted by the law as they are not able to send them back nor keep them alive in Hawaii.
native animals are humanely euthanized, as they are stuck with no place to go or official owner (Frostad, 2019; State of Hawaii PQ Branch, 2018). For example, Maui County inspectors received an agricultural shipment that contained a skunk, which could not be shipped back, so the inspectors had to depose of the animal (Frostad, 2019). The agricultural inspectors on Maui have access to the “destroy room” which has a heat chamber which allows them to safely dispose of invasive plants and infested produce. The amnesty program is also run by the PQ not the AQ, which is confusing to citizens and government officials alike that make reports of exotic or illegal animals.

*Domestic Arrivals: Pet Travel*

The Animal Quality (AQ) branch, located within the Animal Industry (AI) division, mainly focuses on preventing disease and pests that affect Hawaii’s animal farming, such as livestock and poultry (State of Hawaii Animal Industry Division, 2018). The branch also examines pets and runs a veterinary lab to inspect other domestic animals entering Hawaii, specifically with the focus to prevent the arrival of rabies into the state, as Hawaii is the only state that is rabies-free.

To bring a pet into the state, the current program is entitled “Five Days or Less” which encourages pet owners to take the initiative and pay the costs of testing their animals for rabies before arrival. On average the process prior to arrival may take from four to ten months depending on the age and location of the dog, which determines its risk of transmitting rabies. Owners must work with a contracted veterinary service to run medical tests to prove their animal is healthy. Once landed, the pet owner must pay for the contracted veterinarian to meet the plane if they want direct airport release and to briefly confiscate the animal to make sure the pre-approved samples match the physical specimen (Frostad, 2019; State of Hawaii Animal Industry Division, 2018). This process has been well-received by pet owners and the AQ alike, who are
better able to accommodate guests traveling with service or emotional-support animals expediently without posing a risk of bringing a new disease to the islands. The number of pets entering Hawaii increased greatly after the adoption of the “Five Days or Less” program in 2003. Between FY 1997 and 2003, the average number of incoming pets to Hawaii was 4205, while between FY 2004 and 2018, the average rose to 11,835 pets (Maeda, 2019).

This process can also be rather costly and inefficient. If owners do not want to pay for direct airport release, which can range from $98 to $258, the owner will have to wait 120 days before retrieving their animal. This option puts more of the costs on the AQ, who must hold the animal in the Airport Animal Quarantine Holding Facility at the ASIF, if there even is one. For people with anyone traveling with pets, even service dogs or emotional support animals, the process can be overpriced as not all veterinarians partner with the AQ Division to meet incoming animals. Out of those that do, many practices overcharge the travelers, tacking on a veterinary fee the range of costs, from $567-1080 per animal depending on direct release, five day or less program, or the 120 day quarantine (State of Hawaii Animal Industry Division, 2018). These veterinarians raise up costs to run simple exams and tests because they know the pet owners have few options, with the Humane Society offering the lowest cost at $200 and some offices charging as much as $500 per animal. At the Daniel K. Inouye Honolulu International airport, no permit is required to land with a dog or cat, who can be inspected by an official at the AQ branch who run the program during daylight hours, 8-5 pm, including weekdays and holidays (State of Hawaii Animal Industry Division, 2018). All pets and service dogs are sent to the inspector who inspects the pets as a full-time occupation and is able to conduct tests or further studies as needed. This approach reduces the costs for the traveler and makes the process more user-friendly, as opposed to the obstacle course of forms and requirements in place in other locations. For example, on neighboring islands, a Neighboring Island Inspection Permit must be requested over ten days in
advance as these airports are much smaller and do not have staff solely dedicated to animal inspection. This permit adds another cost to the long list of fees and is not user-friendly to the public, as well as increase backlog in the number of species kept at the quarantine facilities unnecessarily just because those animals did not arrive with the right forms completed. Establishing a full-time staff similar to the Honolulu model would reduce costs both for the AQ Division and for travelers by reducing the number of costly tests needed in advance and also limiting the number of animals spending lengthy periods of time in quarantine. This model would also be more convenient for travelers with guide and service dogs, who are able to be cleared more quickly and less inconvenienced.

**Animal Quarantine Facilities**

The only AQ facility in the state is on Oahu, while satellite facilities have been approved on all outer islands excluding Molokai and Lanai (AQ Division, 2019). However, all animals must first pass through the Oahu AQ station. Although the majority of flights and pets do arrive in Oahu, it would be faster and more convenient of each island had a small operational AQ facility. As airports on the outer islands are expanding and more passengers choose to fly directly to outer islands, the infrastructure addition of AQ facilities would help the outer islands to handle the larger demand (L. Kawaoka, 2016).

**Lists of the Good, the Bad, & the Ugly**

To accommodate changing laws and regulations regarding what constitutes illegal wildlife introductions, the state has an updated list of injurious wildlife that may be permitted to leave the state given certain parameters. Injurious wildlife is defined as “any species or subspecies of animal except game birds and game mammals which is known to be harmful to agriculture, aquaculture, indigenous wildlife or plants, or constitute a nuisance or health hazard and is listed in the exhibit entitled” (Division of Forestry and Wildlife, 2013).
Hawaii Wildlife Programs will issue an injurious wildlife export permit to a person leaving Hawaii and already had the animal in their possession, to a visitor as requested, and on a case-by-case basis for research, educational displays, or exhibitions. Once in Hawaii, an injurious wildlife species, such as a veiled chameleon or mongoose, is not allowed to be moved to other islands that may not have been exposed to this species yet and cannot be released into the wild (Division of Forestry and Wildlife, 2013). The enforcement of this policy is unclear, as inspectors are not able to prevent 100 percent of introductions. The policy also fails to follow up when a visitor brings injurious wildlife into the state and then leaves the state, not requiring retroactive penalties if the species was brought in illegally (most likely through mail).

For produce, the HDOA has a “List of conditionally approved animals” which lists 62 pages worth of species that are allowed into Hawaii in certain forms. For example, rats are technically a permitted mammal if the rat is a domesticated variety and is a pet (HDOA Plant Quarantine Office, 2006). The list includes all shellfish that are available for consumption as well as pets (like guinea pigs and parrots) and more odd species such as the bullfrogs, turtles and tortoises, and aquarium fish. The only mammals currently conditionally approved are guinea pigs, chinchillas, mice and rats but other animals, such as livestock, are permitted through a separate form, also processed by HDOA. This list permits species that are either already present in Hawaii and are noninvasive, such as the myna bird, and generally species that are low risk or expected to be contained as pets or in domesticated environments. The issue is that many of these pets escape or are abandoned, leading to large populations of feral animals in Hawaii, which can further harm wildlife. Domesticated rabbits do not even require a permit to import into Hawaii, although this species can reproduce quickly and is also found in populations in the wild (State of Hawaii PQ Branch, 2019). The University of Hawaii’s College of Tropical Agriculture and Human Resources found that the prevention of “[c]ertain high risk, non-essential products
should be banned from importation - like fresh flowers originating from high risk areas . . . " (Rago & Sugano, 2015, p. 94). Although banning flowers from high-risk areas may seem extreme, the rate of species introductions to Hawaii could decrease enormously and the potential costs to inspect the high-risk cargo would be eliminated if the shipment does not arrive in Hawaii in the first place.

The list also has not been updated since 2006, which suggests a lack of continuous research and information gathering to stay informed on what species pose a risk to the state, agriculturally or not. There are also lists of species that have restricted regulations for importing into Hawaii, which may be permitted for research, exhibition, or private commercial use. For example, deer and bison were permitted to enter the state for “private and commercial” use prior to the 1960s, although the deer in Hawaii are known to cause problems by consuming agricultural crops and native forests and the lack of natural predators allow populations to grow out of control (HDOA Plant Quarantine Office, 2006). These lists therefore do not seem to be based on what is ecologically rational but rather on importing species that improve tourism and increase the GSP. Deer is a popular game for hunting, and ranchers have been known to import deer illegally to then sell to clients to hunt (Kubota, 2011). The fact that herds of deer can be shipped to Hawaii illegally without detection signals a lack of effective and thorough inspection procedures at borders. The Big Island of Hawaii, which has been diligent to exclude deer, as of 2011 has thousands of deer, which may be almost impossible to remove economically. Maui, Molokai, Kauai, Oahu, and Lanai all have large deer populations, where the species has been transmitted and shipped between islands with relative ease.

The state is not exclusively focused on what species can enter the state but also on prohibiting certain species entirely. Many species that are known to be invasive are included on the list, such as zebra mussels and chameleons, but the enforcement of these policies has been
weak. Snakes, which are restricted to just six snakes permitted in the state (two nonvenomous snakes for the government zoo and four sterile male brown tree snakes for dog training) are often caught at the border and spotted and captured by inspectors using the 643-PEST hotline. Piranhas are prohibited but frequently kept illegally in aquariums, which have been dumped or released into the wild, introducing the vicious fish to canals and streams (Charisma, 2017). Other exotic species spotted in Hawaii include a population of around 100 wallabies on Oahu, boa constrictors, iguanas, caimans, alligators, and even a golden eagle on Kauai until it was killed by a helicopter (Charisma, 2017). These exotic animals, though prohibited, are most likely snuck in due to the lack of capacity to inspect every bag and the reliance on self-declaration forms, which trust individuals to share what they are importing. As these species often escape from enclosures and homes, a new population of an exotic species develops, which is difficult to track and remove. The list has not been the most effective mechanism for preventing the arrival of invasive species because it is not backed by the funding and personnel necessary to do a thorough job.

**Noxious Weeds List**

There are two levels of noxious weed lists, state and federal, and they do not always align. The state list tends to quickly include species that may pose a risk to the state, while the federal Noxious Weeds list has specific criteria that must be met: “A species can only become officially noxious by meeting all of several criteria. When a weed is no longer considered manageable, it is removed from the list. Currently, plant species listed on the State Noxious Plant list and the Federal Noxious Weed Seed list show little overlap” (Stone, Smith, Tunison, & Cooperative National Park Resources Studies Unit, Hawaii, 1992, p. 827). This lack of overlap means that the portions of Figure # that are run by federal agencies, such as USDA and USFWS, are not regulating and prohibiting the same items and organisms as the state-level agencies. In fact, sometimes these lists can directly contradict each other, with the federal list permitting a
species’ entry into the state and a state policy denying its arrival. The lack of harmonization between the federal and state level makes the list confusing for any company or individual involved with the movement of goods between states and countries, which can harm business or lead to delays. The delays can be extremely detrimental, especially for a time-sensitive business such as produce or fresh flowers, that when delayed may become spoiled and not be able to be sold. The loss of profits and of energy in these delays is caused by the discrepancies between these lists. A delay also takes place before a noxious weed is added to the Noxious Weeds list. This lag time can allow that species to establish itself, shrinking the possibility of a complete eradication and removal.

Miconia, the invasive tree that has taken over the islands of Maui and Oahu, is a dangerous example of the pitfalls of the process. *Miconia calvescens* was recognized as an invasive species within a couple months of its arrival in Hawaii, but hearings and public comment periods delayed adding the plant to the Noxious Weeds List for years (Stone et al., 1992, p. 827). Miconia was added to the state’s Noxious Weeds list three years after its introduction, but still specimens were arriving because it was not also on the federal list (Anderson, 2017; Stone et al., 1992). Miconia arrived in Tahiti in 1937 and the island was virtually consumed by the plant, coming to occupy two thirds of its land area (MISC, 2017a). The plant has caused several landslides, as it grows in such dense populations the soil gives way (see Figure 5.3).
Today, more than 25 percent of Tahiti’s endemic species are at risk of extinction (Danoff-Burg, 2002; MISC, 2017a). Many residents heard of what was happening in Tahiti and wanted to take action in Hawaii, before it was too late. The Melastome Action Committee (MAC) formed on Maui by naturalist Lloyd Loope more than thirty years after the initial introduction of Miconia in 1991 to fill the gap between public federal and state lists to regulate the organism, beginning to recruit volunteers to remove the plants and raise awareness regarding their destructive capabilities (Anderson, 2017). The MAC ultimately became MISC, and other ISCs formed inspired by Maui in the early 2000s (Royce, 2017). Although Miconia was ultimately added to the federal Noxious Weeds list, the action was more symbolic than operational, as over the years the initial Miconia plants had establish vast mono-forests, occupying swaths of land that are likely never wholly recoverable, only manageable (Ashe, 2017). The state new almost immediately that the plant was invasive and highly likely to damage the local ecology yet was
unable to overcome federal legislation to deal with the problem in a timely way. This lack of legislative authority over Hawaii’s own resources and functions leaves Hawaii vulnerable to countless organisms arriving every day.

In general, the Hawaii Noxious Weeds List is more cautious in terms of the species it permits, listing many species that may only be a problem in Hawaii specifically. The National Noxious Weeds List does not consider state specific context into account and acts as if what threatens the rest of the country is the same as the organisms which threaten Hawaii, ignoring community input and ecological differences. As the most isolated island chain in the world, the country as a whole should acknowledge that the level of biodiversity and the breadth of species in Hawaii make it unique, so that the prohibited weeds should be strengthened to protect this precious resource.

*Private Jets and Yachts: Vessels of Exotic Goods?*

The private jet and yacht industries arrivals are growing each year as Maui attracts a wealthy crowd from all over the world. Private transport does not receive the same level of regulation as commercial flights, making them even less inspected and tightly managed. Due to the variability in arrivals and the already overstretched staff, many jets are not inspected, allowing the passengers to bring in plants and animals do not belong, such as a black panther on Maui (Frostad 2019).

*Mail: A Small Success*

In 1995, HDOA was granted the ability to regulate first class mail by federal law. This step allowed HDOA to finally inspect first class mail that may pose a threat to agriculture, as first class mail has often been a pathway for seeds and plant parts (Hawaii Department of Agriculture et al., 2016; State of Hawaii Plant Industry Division, 2019a). However, HDOA may only inspect the packages which have been identified as carrying plants or plant products. Any
agricultural items that are shipped are required by the state to the mail or cargo with the words “Plant Materials” or “Agricultural Commodities” (State of Hawaii Plant Industry Division, 2019b). Anything that is not labeled with these terms or does not indicate any signs of containing organic materials is not passed on to HDOA by the mail carrier. Ideally, all mail could be run through an x-ray machine or sniffed by dogs to determine if it carries any biological tissue which could harm Hawaii. However, the federal law is far from granting Hawaii access to all mail and cargo, but this small change helps the HDOA immensely. Additionally, there are only between three and six dog teams in the state, which is not enough to meet all flights let alone all cargo (State of Hawaii, 2019a).

Ships: Cargo & Cruise Contagion Carriers

Figure 5.4: Detailed Map of Major Harbors and Regulated Areas by DLNR (DAR, 2014)

Ballast water is not regulated, as the coast guard does not test or comply with international regulations (Martin 2019). There is a lack of data available on ballast water as a pathway and Hawaii does not currently know the rate of introductions by sea.

Military Threat
The active presence of the military in over 19 bases and compounds across the islands contributes to the potential pathways of invasive species.\(^1\) As of April 2019, the Department of Defense (DOD) is not subject to the same state laws and regulations of other industries, meaning the ballast water requirements and inspections do not apply (Hawaii Department of Agriculture et al., 2016). As a state, Hawaii does not have the authority to inspect or quarantine cargo, ships, and other vessels used by the DOD, but the DOD is subject to federal legislation, such as the ESA and USDA initiatives, which is enforced via the USFWS. Currently, the U.S. has sixteen territories with a large majority located in the Pacific (see Appendix). Therefore, the five branches of the military sustain a lot of traffic between these outposts, some of which are unpopulated coral atolls, with relatively little regulation or outside quality control. This traffic is said to be what spread the brown tree snake from Papua New Guinea to Guam, which then lead to the decimation of many native birds. The USDA inspects all military aircraft prior to departing to Guam or another military base, but for military aircraft arriving into Hawaii, U.S. Customs and Border Protection, sometimes in partnership with the HDOA, inspects the planes (State of Hawaii Department of Agriculture, 2008). In practice, many inspectors trust military operations to inspect themselves, as the inspectors do not have the ability inspect off-port sites in addition to the airports and ports, which are already not completely investigated (Atwood, 2019).

The Hawaii Biosecurity Plan advocates for an increased partnership between the state and the DOD to ensure that the enforcement of the ESA is done in such a way that is consistent and comparable with Hawaii’s biosecurity goals. Such a partnership would educate the military on the state’s priorities as well as share resources as to the best prevention strategies to mitigate invasive species transmission across the Pacific Ocean and beyond.

\(^1\) This thesis does not completely explore the military pathway due to the lack of publicly available data, but future research should examine the introductions from military sources, especially in such a militarily-active region like Hawaii.
Multi-Agency Efforts

The pest hotline, 643-PEST, has been useful in improving the timeliness of the reports but has yet to be widely adopted by every island, as the majority of the effort has been concentrated on Oahu. Coordinating Group on Alien Pest Species, CGAPS, has been instrumental in the development and distribution of the hotline, as well as in garnering agency support in managing and responding to pest reports (Martin, 2018). Christy Martin, the Public Information Officer and Program Manager of CGAPs, explained that the hotline was slow to expand because CGAPS had to spend “over ten years getting HDOA to [think of it] as their own and take it over” (Martin, 2018). HDOA is still in the process of accepting it but the public has been much quicker to utilize this resource. The number of calls has increased rapidly, increasing the number of eyes on the lookout, and improving the odds of an interception.

Hawaii Interagency Biosecurity Plan: A Big Step Forward

Efforts to address the threat to the fragile ecosystems of Hawaii and possible implications to tourism, agriculture, and the overall health of the economy are becoming more widespread, including 2017 Hawaii Interagency Biosecurity Plan. In 2017, a conglomeration of stakeholders passed the Hawaii Interagency Biosecurity Plan (HIBP). This multiagency plan outlines the approach to prevent the invasions from causing significant economic and ecological damage to the islands of Hawaii (“Hawaii Interagency Biosecurity Plan”, 2017). The Hawaii Department of Land and Natural Resources (DLNR), Hawaii Department of Health (DOH), and the University of Hawaii (UH) act as key players in assisting the Hawaii Department of Agriculture (HDOA) in protecting the islands from the threat of invasive species. This plan was passed under Resolution 17-1 by the Hawaii Invasive Species Council (HISC) which on January 17, 2017 began to coordinate biocontrol efforts between state, international, federal, and private programs ("Resolution 17-1", 2017). The risk that invasive species pose to Hawaii’s natural resources,
tourism infrastructure and facilities, and tourism related businesses may be as much as $8.24 billion (Hawaii Invasive Species Council 2016). The state’s past efforts have not been extremely successful in preventing, managing and eradicating invasive species’ presence in Hawaii. One underlying problem is the lack of infrastructural and technological updates to improve the monitoring and interception of these aliens at ports of entry, such as airports and harbors, as demonstrated by the lack of ASIF buildings.

Start of the Snake Inspection Program

In 2018, the HDOA imported four sterile male brown tree snakes from Guam to use in dog training to help Maui continue to ward of the establishment of this population (H. N. N. Staff, 2018). This process took lengthy permitting and approval due the high risk that snakes pose to Hawaii’s ecosystems (Duvall, 2019). Tree snakes in Hawaii, where no current established snake population exists, would alter the bird life, as it did in Guam. In Guam the birds were decimated by the introduction of the brown tree snakes, who found the bird eggs and behavior very conducive to easy prey (more on this case in Chapter Four). The training of airport and harbor staff to be prepared for snakes is important, as snakes have been found and intercepted on multiple occasions (Frostad, 2019; M. Loope, 2019). Forward-thinking programs such the snake training system will help Hawaii to prevent more invasions, rather than spending large sums on eradication and management.

Another program that has been successful is the Christmas tree program, a collaborative effort between HDOA and Oregon Department of Agriculture. The Christmas trees are pre-screened in Oregon by mechanical shaking (called reconditioning) and inspection (Hawaii Department of Agriculture et al., 2016). By eliminating pests pre-shipping, the trees pose a lesser threat to Hawaii and remove the burden of inspection from HDOA. The screening and pre-shipping policy is held to Hawaii’s state specific standards by requiring Oregon Department of
Agriculture to follow specific building structures for inspection and screening protocols. Because states vary in its border policies, it can be difficult to achieve stringent biosecurity when priorities and risk vary by state. The partnership between Oregon and Hawaii in the Christmas tree industry is a glimmer of hope into perhaps the safest mechanism of prevention, pre-shipping inspection which mutually benefits both parties. Oregon might have been fined by Hawaii for pests or the product could have been detained or damaged in treating it for pests. Hawaii also is able continue this economic relationship while significantly reducing the hazard posed by this pathway.

Overall, Hawaii’s current system is a hodgepodge of agency efforts and funding resources thrown together to do something about invasive species. The policies in Hawaii are not able to handle and reduce the risk invasive species pose to the state and because of this failure, the residents and state are paying the consequence. There is a consensus that the state needs to change its tactic greatly before it is too late, summed up in two main problems; “…1) Hawaii quarantine and inspection systems have been developed piecemeal over the past century, with each piece designed to address only part of the problem; and 2) Hawaii has been treated the same as any other state in international traffic of biological material, despite much greater vulnerability to biological invasions” (Stone, Smith, Tunison, & Cooperative National Park Resources Studies Unit, Hawaii, 1992, p. 827).

Is Hawaii Alone in Its Fight?

Hawaii is not alone in the challenges it faces brought on by invasive species. The next section will examine the approach to invasive species from other nations and islands and compare these frameworks to Hawaii with the hope of learning how to improve the state’s structure.
Chapter 6: International Leaders in Invasive Species Management

The system of invasive species management in Hawaii is not the only way to execute the complicated yet compulsory task of fighting the battle against invasive species. Two main approaches to invasive species by the government or state agency include a cooperative effort between multiple agencies/departments who hold a stake in the success of these initiatives or the establishment of a separate singular agency/department which is responsible for biosecurity alone. The benefit of multiple agencies is that invasive species issues intersect across many industries and interests, as demonstrated in Chapter 1. Additionally, the management of invasive species has been run as a coalition between agencies since the 1990s when the efforts first began. However, the legacy of this management style and its intersectional interests have also muddled efforts to advance and slowed down border management as the communication channels between the agencies are unclear and not always followed. Therefore, a single agency could help to ensure that invasive species is allocated a full budget, not merely receiving a portion of another agency’s funds, and to streamline the lines of communication to ensure the rapid and appropriate protocols are obeyed and standardized. Each agency may be concerned with how well its interests are represented in the single agency, and it would be difficult for a single group to be able to equally weigh priorities between interested parties. There may also be other ways of managing invasive species at the border, which include private-public partnerships, international multilateral environmental agreements, and citizen participation. I will examine what other islands and nations have done to protect themselves from unwanted invasive species to identify what model(s) may work for Hawaii.

New Zealand Invasive Species Policy Framework & Approach

New Zealand’s Biosecurity Act of 1993 works to comprehensively determine which species are permitted to enter the island nation and which are forbidden. The Biosecurity Act
gives the Director-General the role of “facilitating the development and alignment of national pest management plans and national pathway management plans” (New Zealand Government, 1993). The Biosecurity Act also gives a lot of authority to the regional councils, which then are able to “review, amend, revoke and replace, or revoke a plan…” (New Zealand Government, 1993). The pest control plans, separated by national versus regional level, must have a lead management agency which is accountable for providing funds as well as capable of managing the plan in terms of department expertise and agency capacity. The national level handles the ports and pre-entry notices, which has to do with national security and international trade agreements, while the regional territorial authorities manage post-arrival invasive species eradication efforts (McKirdy, 2019).

The process of biosecurity in New Zealand puts the prerogative on those entering the country, be they tourists or cargo, to ensure that they do not pose a risk to the economy, environment, or the public. The Biosecurity Act states “An importer of risk goods must…take all reasonable steps to ensure that the goods comply with applicable import health standards” and all goods crafts, defined as air and water transport, must give notice of their approved intentions to comply prior to arrival (New Zealand Government, 1993, p.44). The notice has specific requirements of outlining where the craft has been and where it intends to travel to, also specifying that once granted, the craft must travel directly to New Zealand without adding stops. Any craft carrying cargo must give a report on the cargo, with sufficient evidence to support the information (New Zealand Government, 1993). If any of these stipulations are violated e.g. a craft arrives after making several stops or the port is not notified of its arrival, the goods are not permitted to leave the craft until an inspector can examine them and a fine is given up to $10,000 for inspecting the craft (New Zealand Government, 1993, p.47).
The Ministry of Primary Industries (MPI) is the organization in charge of regulating borders and the potential risks of various goods and crafts traversing these borders (McKirdy, 2019). A Minister must have first been an elected member of the House of Representatives, a rule known as “confidence of the house” (New Zealand Government, 2019). The MPI has plans for biosecurity operating at the national, territorial, and regional levels, with overlap and coordination between them. At ports of entry, the MPI appoints a “chief technical officer” who creates an “import health standard” which decides whether importing a good could bring a new organism into NZ. If the Director-General issues the standard, any importers carrying that good will be held accountable to updated restrictions or conditions outlined by the standard.

The NZ government also has strict craft risk management standards, which apply to all crafts entering, exiting, and remaining in NZ territory including the exclusive economic zone of sea territory (EEZ) (New Zealand Government, 1993, p.55). For both standards, the NZ government takes into account the threat to “…human health, the New Zealand environment, and the New Zealand economy of the organisms that the craft may import into New Zealand territory” (New Zealand Government, 1993, p. 56). The Biosecurity Act of 1993 does not mention tourism once, instead focusing on the main risks of invasive species as vectors of disease and ecological disruption.

All goods are taken to a “transitional facility” or “biosecurity control area” to be authorized by an inspector, at which point they are cleared to enter (New Zealand Government, 1993, p.57). If goods are risky but comply with risk management techniques associated with the health or craft standards, the goods may still be cleared. All cleared and uncleared goods are posted on the MPI’s website, stating the reasons behind the decision. This process holds inspectors accountable as well as provides a transparent document trail between importer and inspector.
If an organism is discovered, until the organism is determined hazardous, “the estimated costs and expenses of the custody and maintenance of the organism must be paid in advance to the Director-General by the importer” (New Zealand Government, 1993, p.63).

Philosophically, “all goods and craft are deemed risk goods until proven otherwise” imparted Andrew McKirdy, Senior Business Analyst with the Intelligence Planning and Coordination Services for the MPI. The risk comes with a cost. New Zealand has implemented a border clearance levy, included in the cost of air and cruise travel, both for arrivals and departures to prevent the spread of invasive species and fund biosecurity for island. This fee is used by the New Zealand Customs Service and the Ministry for Primary Industries to improve technology and allow staff to micro-manage every level of arrivals and departures. The fee also reflects a move to have those posing a risk to the country, the travelers, pay for the risk they pose to the borders (NZ Customs Service & Ministry for Primary Industries, 2017).

Some ports are approved by the Director-General as “places of first arrival” where the ports are capable of inspecting incoming craft due to the presence of approved facilities and the facilities’ use incurs a reasonable cost on the port operator (New Zealand Government, 1993, p.73). Places of first arrival can be revoked if the transitional facilities no longer meet standards or the port operator is acting dishonestly. The ports have transitional facilities which can serve as inspection facilities of cargo and craft, to detect and remove of all invasive species prior to landing. NZ has approximately 7000 transitional facilities at wharfs and on land across the country (Hustedt, 2010). All border ports are part of the Joint Border Management System (JBMS) which allows them to share information regarding goods, crafts, importers and exporters, and persons (New Zealand Government, 1993, p. 87). Every person entering the country has a duty to provide information to the government regarding the presence of unwanted organisms of any kind.
The costs of compliance at ports is approximately one percent of the value of the annual imports (Hustedt, 2010). The investment in a large staff of quality inspectors has increased the efficiency of detecting slippage (where contaminated goods make it through biosecurity) to the extent that 94.25 to 98.37 percent of all goods pose no risk to the people and places of NZ (Hustedt, 2010). NZ previously permitted inspectors to meet the high demand of increasing import partners into the country by looking at the percentage of total imports that posed a risk and inspecting that percentage of crafts (Hustedt, 2010). However, beginning in 2005, NZ resumed 100 percent inspections to avoid inefficiencies and slippages that inevitably occurred with the risk analysis partial inspections.

New Zealand has also passed the Hazardous Substances and New Organisms (HSNO) Act of 1996 which partially involves invasive species management or the management of “new organisms.” A “New Organism” is defined as a species not found in New Zealand prior to July 29, 1998 and a risk species that poses a risk to the environment (New Zealand Legislation, 1996, p. 29). A primary concern of the act involves genetic engineering and the presence of potential toxins in food, agricultural pesticide use, and other environmental hazards, which is why the act is ministered by the EPA of NZ, the Ministry of the Environment. The HNSO Act would work with the Biosecurity Act to ensure that all new organisms do not bring in new hazards and pass biosecurity requirements (McKirdy, 2019). Any person wishing to bring a new organism into NZ must apply for approval from the Ministry of the Environment, who keeps a public record of the applications, previous approvals/denials, and related acts (New Zealand Legislation, 1996, p. 41). Anyone who attempts to import a hazardous substance or new organism must ensure that the item will not cause “adverse effects” on other people or the environment. This stringent requirement has prevented introductions in NZ.
While the Biosecurity Act and the HSNO Act both fall under the MPI, passengers and their baggage along with cargo and mail, are searched by the New Zealand Customs Service (NZCS) which searches for contraband (Hustedt, 2010). Although Biosecurity is handled by MPI and Biosecurity NZ, the revenue raised from NZCS excise, sales, and import tax is the second largest source of revenue for the government second to the Inland Revenue Service (Hustedt, 2010). NZCS and MPI work closely at borders, inspecting cargo and passengers alike for their discrete goals. Both border agencies participate in the intelligence based risk assessment system, called the Trade Single Window, which is an online communication network between importers and exporters to MPI, NZCS, Maritime NZ, and the Ministry of Health (New Zealand Customs Service and Ministry for Primary Industries, 2013).

Hawaii has looked at having a black list versus a white list. A black list has a list of species or pests that are excluded from Hawaii and “blacklisted”. A white list is the reverse, offering a list of all items that are permissible into the state. The difference in the approach can have extremely different results. A black list requires a constant upkeep of which items are threats or might be invasive. Sometimes lists, especially the Noxious Weed List in the United States, take time to update to the point that an introduction and even establishment of a species may have occurred prior to the species’ confirmation on the black list. A white list, however, assumes that various flora and fauna that are confirmed and proven to be low risk are approved to cross borders, but anything not confirmed to pose no threat must be investigated. This approach is the more cautious of the two, because it does not assume that all species are innocent (unlikely to cause damage) until proven guilty. Due to the rate of introductions occurring at borders, it can be difficult to update either list with approved species or unlawful species.

*One Agency or Multiple? Strength in Numbers?*
New Zealand contrasts Hawaii as one agency handles everything related to invasive organisms, even if those species relate to other categories. For example, with rats as vectors of disease, MPI still works to eradicate and prevent the arrival of rats, while the Ministry of Health plays a larger role in disease treatment and diagnostics. Andrew McKirdy, Senior Business Analyst at MPI, maintains that “it is fair to say the Biosecurity Act is an exemplar of legislation worldwide for the prevention of the introduction of harmful organisms… And MPI, as the single agency responsible for biosecurity, is clearly also an advantage…nothing comes into the country without first being screened in some fashion by MPI” (McKirdy, 2019).

Summary

The NZ system perhaps relies too much on public-private partnerships to inspect facilities. However, the system of fees and the large number of devoted staffs has made NZ very biosecure. Hawaii may not be able to impose a tax, as it is only a state and not a country. Other islands with budgets comparable to Hawaii have been able to improve prevention significantly, such as the Caribbean.

Caribbean Overseas Territories & Bermuda Invasive Species Approach

The Caribbean is home to many rich and diverse island communities which face many of the same threats as Hawaii. The Royal Society for the Protection of Birds (RSPB), formed by an anti-hat activist in the United Kingdom in 1889, has taken on the ambitious task of improving the biosecurity measures in the nation’s 14 oversea territories (Koblentz, 2010). The focus of the legislative effort of the government have been primarily on goods and pests that would impact agriculture, not species that may harm the native wildlife. Inter-island biosecurity, both between oversea territories and between islands within a territory, is not regulated or considered (Koblentz, 2010). The results of several case studies conducted by the RSPB are summarized
below, depicting the current success of various levels of leadership and authority at preventing and eradicating invasive species from these islands.

<table>
<thead>
<tr>
<th>Legislative Instruments</th>
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<th>CAYMAN ISLANDS</th>
<th>MONTSERRAT</th>
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</table>

Figure 6.1: Strength of Instruments Supporting Biosecurity and Invasive Alien Species Management (Koblentz, 2010)

All island nations received a “moderate score” for pre-border and at point of entry. As of 2017, none of the oversea territories or Bermuda had actually formed a document that integrated all legislation related to biosecurity or invasive species management; in fact, none of the existing legislation included the words “biosecurity,” “invasive species” or “alien species” (Koblentz, 2017). To add Hawaii to the chart, the pre-border and interisland security would be classified as weak, as Hawaii currently spends less on these measures than the islands here.

Compared to the Caribbean islands and Bermuda, Hawaii’s legislative and policy frameworks seem to be slightly ahead in that they have done more than acknowledge the threat and are actively seeking to improve their methods via prevention at border sites. The HIBP is a progressive move that attempts to integrate various policy mandates between state agencies, passed in 2017. Both Hawaii and the Caribbean overseas territories have regulations which rely on inspecting and managing risk on known pathways, such as the importing of live material. Neither region has switched to a white list, which would assume that not all pathways for species
introductions are known and that all pathways must be tested before assumed to be safe. Many of the overseas territories, which received a moderate score on pre-border and point of entry legislative instruments, actually have not been extremely proactive in their efforts. For example, Bermuda focuses mainly on invasive species management, and within this strategy of eradication, principally targets the invasive lionfish population (Copeland, 2017). The National Environmental Management Strategy and Action Plan of Anguilla only mentions the “control and eradication of invasive species” to “ensure the protection and restoration of key habitats…” and briefly states that the island must do all it can to mitigate possible introductions, without specific guidelines on how that will be accomplished (Homer, 2005). These islands, while beginning to think about the harm of invasive species, have fully developed their approaches to prevent their arrival in the first place, at the detriment of their islands’ landscape and wildlife.

The Caribbean overseas territories raise an important point with regards to question how to handle the multiagency approach to invasive species management. The inspection officers already have the legal basis needed for inspection, destruction, and quarantine of commodities that may pose a threat to agriculture. No other agency has been as actively involved at the pre-and border levels of inspection, as other agencies mainly focus on post-border eradication, early detection and rapid response in the field, and control or management of invasive species. The RSPB report recommends that the agricultural inspectors expand their search to prevent invasive species that not impact agriculture but may be detrimental to the native ecology or to human health (John, Radford, & Cleminson, 2017). For example, the Bermudian Ministry of the Environment was informed of several cases of Zika virus acquired abroad in Bermuda, which led to a heightened study of the local mosquito population (Copeland, 2017). These inspectors may have to be trained to inspect for pests that previously were not regulated but the system benefits
from their built-up knowledge and adding to their repertoires, versus starting over with new inspectors.

Only the Cayman Islands exhibited a substantial effort to regulate inter-island travel and trade. The lack of work dedicated towards managing inter-island borders reveals a flawed system that does little to protect the islands from the arrival of a threat. Inter-island management of invasive species would protect unexposed areas from the threat even if a species makes it through border security, which helps to prevent the spread of an organism across an entire region. The failure of the majority of the overseas territories to understand this key concept will lead to a wider distribution of invasive species that could have been proactively managed and avoided (John et al., 2017).

There are many obstacles to improving invasive species management in the Caribbean that are paralleled in Hawaii. Generally, government organizations can only interfere in the name of invasive species on lands entrusted for conservation. These laws exclude invasive species efforts from preventing invasive species outside of protected areas except in the Cayman Islands and Montserrat, which limits the scope of what invasive species post-border policies and resources can accomplish (John et al., 2017). Hawaii ISCs similarly are prevented from entering non-public lands, which restricts the field crews to working in national parks, conservation areas, and state forests. To go on private property, the ISCs must receive a warrant from the courts, which is a bureaucratic process which can take many months, at which point a species has moved or added to its population and distribution. The lack of the legal synchronized framework that would permit a timely response to invasive species is further reinforcement of the need for prevention. In the Caribbean, both the Turks and Caicos Islands and Anguilla have legislative efforts to improve biosecurity that have been stalled since 2008 (John et al., 2017). The legal changes to help ISCs and the Caribbean governments investigate all hazards across all lands is
still a battle worth fighting but the invasive species problem cannot be delayed by its entanglement in the law. Prevention is therefore not only a relatively cheaper policy approach but also a quicker tactic to put the plug in the invasive species’ leak.

Another argument for prevention includes the discussion on how to handle invasive species that are intercepted at island borders but cannot be returned to the home country. The British Virgin Islands inspectors are permitted to impound livestock and other live imports and may destroy or euthanize these animals as they see fit (John et al., 2017). The National Plant and Animal Habitat Policy of 2001 in Anguilla gives the local government the power to control invasive species but does not explicitly mention how (John et al., 2017). These advances give applicable solutions to similar problems in Hawaii, as well as demonstrate the ongoing global study and changing practices in invasive species management.
Chapter 7: Policy Recommendations

New Zealand’s biosecurity reveals potential options for a successful invasive species system in Hawaii. The primary results include that the nation as a whole has prioritized invasive species management as a national program, meaning the entire effort is incredibly well-funded, staffed, and resourced. Hawaii in the long-term should work to push the U.S. as whole to better protect the country’s assets via strong invasive species policies. In the short-run, Hawaii as a state can use New Zealand as an example of an island community that is taking preventative steps to offset a future of mass extinctions and losses in agricultural output and human health. New Zealand’s philosophical approach based on the precautionary principle leads to a system which is much more cost-effective and handles the uncertainty of a specie’s invasiveness in a way the reduces harm. The technology used in New Zealand also streamlines the process for businesses and inspectors alike, so that invasive species efforts do not threaten the success of other industries. The primary recommendations for Hawaii based on a study of the international field include increasing funding (potentially by holding importers responsible for their actions), adding inspection facilities, regulating inter-island travel, adopting an electronic risk-management system, and start an emergency fund to rapidly handle anything unexpected. These policy changes may vary based on the decision to switch from a predominantly black list framework to a white list (or somewhere in between), and whether Hawaii decides to consolidate the interagency approach into one centralized invasive species agency. These alternatives are considered in detail in the following section.

Funding is Necessary

Funding for the HIBP should be prioritized and expanded as it will reduce costs in the future and affects almost every industry and person across the state. The ability to respond to emergency situations, such as the arrival of a snake or new pest, is limited by the lack of funding
to manage such a situation. This lack of funding, specifically emergency funds, has contributed to the arrival of the little fire ant, the banana bunchy top virus, the coffee berry borer, several snake specimens, and more (Hawaii Department of Agriculture et al., 2016). If the funding was granted proactively versus retroactively (as it is currently to deal with eradication), less money overall would be spent as the populations are the smaller and the area of contamination is more restricted.

**Adding Inspection Facilities to Increase the Interception Rate**

Improving the number and capacity at inspection facilities will help Hawaii to better protect its shores. An inspection facility that is able to inspect 100 percent of imports and goods increases the chance of intercepting an unwelcomed pest. If inspectors are able to meet every plane and boat, the number of illegal and accidental introductions will decrease significantly. The agencies involved will also have more power and resources to enforce policies that have not been correctly followed, such as ballast water treatment methods, fumigation of planes and passengers, and following up on the self-declaration forms (Delach, 2016; Hawaii Department of Agriculture et al., 2016). Ideally, an inspection facility manned with full-time inspectors and in alliance with airlines and other inbound partners would be located at every harbor, dock, private airstrip and runway on the islands. However, since the majority of goods enter the state through Honolulu Harbor and Honolulu International Airport on Oahu, the largest and most well-resourced inspection facility should be built there, to intercept the invasive species before the cargo is then sent off to the outer islands.
The major airports (Kahului, Hilo, Kona, Honolulu, and Lihue) would be a high priority along with the main harbors (Hilo, Keauhou, Lahaina, Honolulu, and Pearl Harbor). Currently the only inspection facilities exist in full operation on Maui and Oahu, but the Big Island must also develop stronger inspection capabilities due to the pattern of high-risk invasiveness originating from shipments on the Big Island.

**Inspecting Inter-Island Travel**

Hawaii PQ and AQ inspectors need to treat inter-island travel as equally dangerous as intercontinental travel. The distribution of invasive species is not consistent across each of the main islands, so taking measures to prevent the spread of vectors between locations will help increase the likelihood of containment. The total number of passengers traveling between islands on flights is estimated to increase to over 3.5 million passengers annually by 2035 (L. Kawaoka, 2016). Unless the airports inspect these flights, a snake introduction on one island could lead to a snake infestation on another. The ocean barriers between the islands are a natural advantage that could be capitalized upon in managing invasive species arrivals. ROD is not currently impacting
trees on Maui and mongoose do not exist on Kauai. These small wins translated to huge savings for the state and benefits to the local community and ecosystem. It does not seem infeasible to declare that all passengers must be inspected regardless of final destination. By adding inter-island flights to the inspection list, the amount of infrastructure and staff will only need to increase marginally, as the inter-island travel is a large portion of total flights (25,000 annually compared to 11,000 overseas flights) but carry less people/cargo on board, the passengers tend to have less luggage, and many travelers are locals, who are more familiar with Hawaii’s invasive species efforts (L. Kawaoka, 2016). Currently, Maui plans to expand and move its air cargo and alien species inspection facility (ASIF) by 2035 (L. Kawaoka, 2016). Other islands should follow suite, as the number of visitors and good entering Hawaii only increase each year.

As tourism continues to grow, stimulating the economy, Hawaii needs to make an equal effort to protect its residents from the negative aspects of this increase through prevention funding. The state DOT has allocated $2.972 billion for its 20 year plan to improve the Kahului airport and extend the runway to land larger planes from farther distances (L. Kawaoka, 2016). Although the cost of building an ASIF is included in this estimate, the state has demonstrated financially that it is committed to expanding tourism opportunities and has yet to do so with addressing invasive species. The resources spent on invasive species prevention should be seen as an investment in tourism and continued GSP growth, not as a tangential issue.

Modernizing the System: Integrating Technology and Risk Management

The members of HISC as well as CGAPS staff advocate for an electronic risk assessment software and database to identify patterns in invasive species arrivals (Burnett & Coffman, 2015; Hawaii Department of Agriculture et al., 2016). The system would be crucial if funding is not increased substantially for other measures, such as inspection facilities and more staff. An online risk-assessment program could help inspectors judge which imports may pose a larger risk to
Hawaii based on a variety of factors, such as a past history of invasiveness, certain ecological characteristics, country of origin, etc. Cargo and flights that are then calculated to be high-risk should be inspected and prioritized before inspecting low-risk pathways, such as passengers themselves. This system would also help to coordinate inspection knowledge between the islands, which do not face the same threats and could help to warn protected areas of species to look out for. Many inspectors also mentioned the need for e-manifest technology for imports (Atwood, 2019; Frostad, 2019). E-manifest technology is already widely used in New Zealand where businesses and nurseries list the completed efforts to mitigate invasive species as well as submit this documentation online to the necessary party prior to arrival. This system would streamline inspections at borders, reduce congestion, and prevent the arrival of invasive species even before an item is shipped.

Switch to a White List?

The Noxious Weed list is ineffective for Hawaii because it is dictated by the Federal government versus the state and does not promote a proactive approach, instead permitting the arrival of invasive species that become problems for the state often when it is too late to successfully remove them. HDOA Supervisor of Plant Inspection Marshall Loope describes two differences in creating a list of weeds: the black or “dirty” list, and the white or “clean” list (M. Loope, 2019). Hawaii currently uses a black list, where items are added to the list once discovered to have a negative role on a host ecosystem. Therefore, the list contains what species are banned and not permitted into the state. For species that very little is known about or where no one knows if it is good or bad, these organisms are permitted in until it is discovered they are bad and then they may be black-listed. Alternatively, a white list positively frames what is allowed to enter, by only permitting species where it is known that the species will have a positive to negligible impact on the host ecosystem. This way, if data is insufficient, it is
assumed that they are bad until proven good, versus with the black list assumed good until proven bad. The white list is significantly more cautious and well-informed (Penniman, 2006). The white list could be used to justify access to properties to remove invasive species that are currently not on the Noxious Weeds List, giving the ISCs and HDOA more legal flexibility in how to remove invasive species populations.

A white list would require a massive effort on the side of research, most likely at UH and CGAPS, to identify threats in a timely way. Unless resources appropriated to research are expanded greatly, it would be more appropriate for Hawaii to adopt a combination of the white and black list approach. Independent organizations, such as Defenders of Wildlife, calls for a national switch to a white list to error on the side of caution: “…make Prevention our top priority by…revers[ing] current U.S. policy on the international import of live plants and animals, that is, switch from a ‘dirty’ to a ‘clean’ list approach that requires screening for invasiveness before import and which keeps out or limits import of species so as to prevent harm to native species or ecosystems – and make the legislative changes to do so” (Delach, 2016). Advocating for additional research on predicting invasiveness could avoid situations like ROD, where the ambrosia beetle was not known to be threat at the time of introduction.

The HIBP does not mention the impact invasive species have on cultural practices, as well as acknowledge the harm done by invasive species to native Hawaiian peoples. The NZ Biosecurity Act of 1993 does this, equating reducing the impact on Māori people as an equal priority as reducing the impact of invasive species on the environment or human health (New Zealand Government, 1993, p.93). Consulting with native groups and community forums, such as the meetings held by CGAPS, should be taken seriously. The comments and input on which species should be thought of as an invasive species problem cannot be decided by the HDOA alone but
by other parties affected in the state, which will increase awareness and participation in Hawaii’s prevention efforts.

**Citizen Education: Joining the Fight Against Invasive Species**

Many residents in Hawaii are aware of the invasive species problems but are less aware about what they can do to help. To prevent the spread of invasive species to Hawaii, visitors should clean all apparel and shoes prior to stepping foot on the plane or cruise ship. Hiking boots and clothing can carry seeds and soil which can transmit a new plant or microbe. If these items are cleaned, ideally with a disinfectant like rubbing alcohol, any viable dirt will have been removed or destroyed. Also, the movement of produce, such as a Florida orange, could introduce a new pest that could pose a huge problem to Hawaii’s agriculture (Frostad, 2019). Therefore, conscious citizens should consume any produce prior to arrival and dispose of the peels in the appropriate airport waste bins before exiting the airport or harbor. Additionally, citizens should consider the impacts of their actions on the society at large before importing an illegal animal, be it a pet or hunting game, into Hawaii. These impacts can forever alter the species composition of Hawaii beyond the lifetime of an individual and hurt other aspects of society greatly.

Therefore, a small fraction of resources should be spent to educate the public, including travelers, on invasive species and the risks they produce. A cost friendly mechanism could be to hold a state-wide competition between schools to create videos or poster content on invasive species in their area. Additionally, the state could air Public Service Announcements that have already been created by nonprofits and independent organizations, such as MISC, the Sierra Club, the Nature Conservancy, and the Hawaiian Island Land Trust.

**Integrate Agency Mandates or Continue to Rely on Cooperation?**

Hawaii could address the gaps in agency mandates in several ways. Depending on the context, one method may be advantageous over another, but all would be an improvement of the
current patchwork of policy. The state could develop the HISC into a state agency, as in New Zealand where there is a Department of Biosecurity within the Ministry of Primary Industries (McKirdy, 2019). By having one agency solely dedicated to invasive species prevention and eradication, the confusion of the past over which group is involved when would be eliminated. However, the agency may receive opposition from other agencies that are critically impacted by its decisions, such as HDOA, DOT, DOH, DLNR, and the ISCs. Therefore, the agency would have to find a way to manage all of these agencies’ interests and still collaborate with the inspectors. A benefit could be that this new umbrella agency would have the right to inspect all goods and items related to invasive species, including mail, private property, and military bases, areas that currently have become entry points.

Alternatively, HDOA has become the primary foot soldier in the battle against invasive species and could be expanded to do so in a more intentional way. HDOA could add staff in a branch directly focused on targeting invasive species, split into the phases of invasive species management: pre-border, border, and post-border, as seen in the figure. Having personnel dedicated specifically to pre-border partnerships or only to border inspections could help HDOA to improve its rate of interception.
HDOA has the benefit of already serving as the leader on invasive species management at the border and has historically received the most funding to complete its initiatives. This path would work within the current status quo and formalize the process instead of inventing a new approach. The staff of HDOA has some training and institutional knowledge which can be built upon and passed on to new staff. HDOA could then be the hub for invasive species border and pre-border management, operating the 643-PEST hotline and working with researchers to determine new risks and threats in a timely manner. This method would streamline the channels of communication instead of the current system of DLNR and DAR managing marine introductions and the U.S. Postal Service involved in some terrestrial introductions to HDOA as the exclusive leader and coordinator of all invasive species projects. The DAR, the DLNR, specifically the DLNR Division of Forestry and Wildlife, and the NPS could then singularly focus on eradication and post-border projects to protect forests, natural assets, and sacred sites versus additionally managing ballast water and marine introductions. The downside would be that it may be difficult to expand HDOA’s mandate beyond agriculture so that the agency is concerned with species that may harm biodiversity or human health. Therefore, this option may depend on the national level and if the U.S. federally establishes that organisms beyond that which impact agriculture should be regulated. At the state level, the proposal for a Hawaii Invasive Species Authority did not pass in 2017 but has been voiced as a desired option by many legislators (State of Hawaii DLNR and Division of Forestry and Wildlife, 2017). The Hawaii Invasive Species Authority would be “an attached agency with dedicated staff and additional board seats to engage industry and other nongovernmental experts” (State of Hawaii DLNR and Division of Forestry and Wildlife, 2017). The new authority would be administratively housed in HDOA versus the current structure of housing HISC within DLNR. During the 2017 legislative
session, 40 bills regarding invasive species were introduced, including HB 1013 “Relating to Invasive Species Program Administration” which transform HISC into the Hawaii Invasive Species Authority. The move was supported by both DLNR and HISC, but did not pass like 34 other bills due to not being scheduled for a subject matter committee hearing meeting, not scheduled for a Finance or Ways and Means meeting, or for deferred by conference committees (State of Hawaii DLNR and Division of Forestry and Wildlife, 2017). Therefore, it is highly probable that within the next couple years, once the details have been fully excavated, the HISC will become the Hawaii Invasive Species Authority, undoing the years of patchwork and gap filling.

Start an Invasive Species Emergency Response Fund

The State Legislature should allocate specific “rainy day” funds to HISC and HDOA for emergency invasive species management. For example, the 643-PEST hotline and app are not able to follow up on every report in a timely fashion and in the lag time, an invasive species can escape or hide. The ability to catch an invasive species at the border before it is released into the wild is a time-sensitive issue, so the addition of emergency funds to prevent an introduction is imperative. The HIBP recommends an emergency response fund along with other state reports which would help Hawaii to increase prevention capacity at crucial moments (Hawaii Department of Agriculture et al., 2016; Rago & Sugano, 2015, p. 173).

Brief Summary

Should the state adopt just one of these initiatives, Hawaii would be much better off. The benefits of prevention are plentiful and cost-effective and give eradication efforts a higher chance of succeeding in the future. Unless some sort of prevention measure is taken, Hawaii will continue to bleed exorbitant sums of money to invasive species related problem, including the
loss of property values, tourism, agriculture products, forests, and water availability and the increase in infrastructure damage, and health hazards.
Chapter 8: Conclusion

The largest conference held in the United States in 2016 was not for a sporting event or famous entertainer but for the World Conservation Congress. The WCC had a record-breaking turnout with over 10,000 attendees and was the first WCC hosted in the U.S. (Hawkins, 2016). The momentum to work to protect the special places of the planet is only growing, which is a good sign for the invasive species movement, which has been mainly restricted by funding. As more citizens realize the impact of their existence on the planet, they also begin to see that invasive species affects many aspects of the environment that we take for granted. Environmentalists, economists, farmers, and conservationists alike are deeply concerned about the ways in which invasive species impact Hawaii. All parties are spending more resources up front to prevent the arrival of invasive species in the first place.

Such a widespread issue is timely and deserves more attention now before Hawaii becomes the next Guam. As the HIBP concisely summarizes “there are numerous examples where a lack of dedicated funding or immediate, coordinated efforts for detection and eradication allowed newly detected pests (in the vicinity of borders or beyond)…to become established, leaving no other option than expensive and perpetual containment or control” (Hawaii Department of Agriculture et al., 2016). It is no longer acceptable to spend less than 2% of the state annual budget on an issue that will only continue to cost increasingly larger sums of capital to fix in the future. Invasive species prevention is timely, bipartisan, and imperative to the status of Hawaii as an irreplaceable global treasure in biodiversity.

Prevention of the species in the first place is crucial to securing Hawaii from new pests and diseases and will increase the success of eradication and other post-border efforts. Mimicking New Zealand’s white list philosophy, based on the precautionary principle, will help Hawaii to avoid the litany of unknowns regarding a specie’s invasiveness. A strengthened black
list will help the state to dictate its own rules on prohibited weeds and plants brought by agricultural importers and nurseries. Expanded inspection facilities and updated technology, as well the re-investment in dog trainings and databases, will fortify Hawaii’s borders, reducing the invasive species problem immeasurably. Health outbreaks such as rat lungworm disease could potentially be avoided, with importers proving that an introduced species will not put Hawaii’s people at risk. The restructuring of HISC as the Hawaii Invasive Species Authority may also promote a clear efficient vision for future invasive species policies, breaking away from the patchwork history of invasive species work as a side project. Hawaii’s team of policymakers, field teams, citizens, and businesses are on track to improving the crisis in Hawaii to something that is manageable and achievable. These changes should be implemented as soon as possible, to begin to change the tide in the narrative on invasive species from one of losses to success.

Charles Elton, the Father of Invasive Species research, declared that the activities of humans has created “one of the great historical convulsions of the world’s fauna and flora” (Cox, 1999, p. 7). This thesis reveals science and policy work do not also complement one another in the methodologies and approaches. Science revolving around invasive species has, by the nature of scientific research, large gaps of uncertainty, producing statements that cannot be viewed as black and white. Politicians and decisionmakers, on the other hand, must address policy problems and take a position on a topic, the result of that decision determining the funding and implementation of a solution. Policymakers seem inclined to solve problems that are based on known data, which is a barrier to addressing a field like invasive species where there are so many unknowns (Will this species be invasive? What are the costs of its introduction to Hawaii? When will it arrive and become a problem?). It is a difficult to wage a successful argument when a legislator cannot answer these questions, which are rooted in the historical framework for environmental policy of cost-benefit analysis and black lists. Therefore, policymakers must
understand the way science operates well enough to justify enormous costs spent towards projects clouded by uncertainty. These leaders must trust that the impacts of invasive species, if the policy framework is left as is, would inextricably alter the environment of Hawaii in ways that be irreversible.

The argument to fight against invasive species in Hawaii is also deeply tied to larger popular environmental movements in the U.S. and beyond. Hawaii no longer exists in isolation and the globalized world must work together to reduce the spread of harmful invasive biota. Unless these partnerships are established, Hawaii will continue to face increasing rates of introductions and must keep spending enormous sums on prevention when this budget could be used for other beneficial causes. A globalized system that understands the biological implications of its actions would increase the longevity and health of the planet as a whole by reducing the likelihood of invasions. The battle for invasive species management cannot be won until there is a global commitment to collaborate on these efforts and restore landscapes to maximize societal benefits and ecosystem functioning. The limitations of scientific knowledge on invasive species only entrenches the need to take action now, to prevent these species, before it is too late.
Appendix

Figure 1: Map of Hawaiian Islands with Major Airports (Hawaii Travel Online, n.d.).

Figure 2: Military Dominance in Hawaii (Wiki Travel, 2018)
Figure 3: HDOA Organizational Structure Chart (State of Hawaii PQ Branch, 2018).

Figure 4: Life Cycle of Rat Lungworm Disease (Napili Farmers Market, 2017)
STATE OF HAWAI'I
Department of Agriculture
PLANTS AND ANIMALS DECLARATION FORM
MANDATORY DECLARATION
FOR ALL PASSENGERS, OFFICERS, AND CREW MEMBERS

ALOHA and Welcome to Hawaii. Many plants and animals from elsewhere in the world can be harmful to our unique environment, agriculture, and communities. Please help to protect Hawaii by not bringing harmful pests into our state.

YOU ARE REQUIRED BY STATE LAW TO FILL OUT THIS AGRICULTURAL DECLARATION FORM. Any person who defaces this declaration form, gives false information, or fails to declare, prohibited or restricted articles in their possession, including baggage, or fails to declare these items on cargo manifests is in violation of Chapter 150A, Hawaii Revised Statutes, and may be guilty of a misdemeanor punishable, in certain instances, by a maximum penalty of $25,000 and/or up to one year imprisonment. Intentionally smuggling a snake or other prohibited or restricted article into Hawaii is, in certain circumstances, a Class C felony punishable by a maximum penalty of $200,000 and/or up to five years imprisonment.

One adult member of a family may complete this declaration for other family members.

A) I HAVE THE FOLLOWING ITEMS IN MY POSSESSION AND/OR BAGGAGE:
☐ Fresh Fruit & Vegetables  ☐ Soil, Growing Media, Sand, etc.
☐ Cut Flowers & Foliage  ☐ Live Seafood (lobsters, clams, oysters, etc.)
☐ Rooted Plants & Plant Cuttings, or Algae  ☐ Cultures of Bacteria, Fungi, Viruses, or Protozoa
☐ Raw or Propagative Seeds or Bulbs  ☐ Insects, Live Fishes, Amphibians, etc.

Please submit all of the above-marked items in your possession and/or baggage for inspection to a Hawaii Plant Quarantine Inspector in the baggage claims area. The cargo agent will submit cargo for inspection on your behalf.

B) I HAVE THE FOLLOWING ITEMS IN MY POSSESSION AND/OR BAGGAGE:
☐ Dogs  ☐ Reptiles (Turtles, Lizards, Snakes, etc.)
☐ Cats  ☐ Other Animals
☐ Birds

If you are traveling with any LIVE ANIMALS, you must NOTIFY A CABIN ATTENDANT PRIOR TO DEPLANING. All live animals must be turned in to the Honolulu Airport Animal Quarantine Holding Facility by the transportation carrier, not the passenger, upon arrival.

☐ NONE OF THE ABOVE

PLEASE LIST THE SPECIFIC TYPES/NAMES OF THE ITEMS MARKED ABOVE.

(Items meeting State requirements will be inspected and released.)

1. ____________________________________________________________

2. ____________________________________________________________

3. ____________________________________________________________

4. ____________________________________________________________

Origin (State or Country) of above items ____________________________________________________________

Full Name (Print) ____________________________________________________________

Home Address ____________________________________________________________

City __________________________ State ______ Zip ______

Hawaii Address or Name of Hotel/Lodging ____________________________________________________________

Island ______________________ Phone No. ____________________________

Name of Airline/Ship ______________________ Flight No. ____________________________

Date of Arrival __________________________

Signature __________________________ Date __________________________

See Reverse Side

HTA Form Rev. 02-01-2016 Printed in U.S.A.

58844
Figure 5: Self-Declaration Form Given to Passengers Arriving to Hawaii Front Side (author’s photo)
Figure 6: Self-Declaration Form Given to Passengers Arriving to Hawaii Back Side (author’s photo)

Figure 7: Majority of U.S. Territories are Concentrated in the Pacific Ocean (King, 2005).
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