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Conserving Chelonia mydas Populations in Oahu: The Impact of Plastic on the Hawaiian Archipelago

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Abstract

This paper addresses the anthropogenic factors that hinder the survival of the once-endangered Hawaiian *Chelonia mydas* population and the associated environmental degradation faced by the Hawaiian Islands. Chapter 1 introduces quantitative data on the decline and gradual recovery of the Hawaiian Green Sea Turtle (*Chelonia mydas*). By understanding the origin of the inhibition of the Hawaiian *Chelonia mydas* population growth and its correlation to the demise of coral reef health, the future viability of recreational fishing and ecotourism can be determined. This chapter studies the cultural significance of this species and evaluates the current stance on government support for the establishment of recovery and conservation efforts. Chapter 2 is founded on the chemistry of pelagic plastics and provides data on the negative presence of abiotic hindrances posed on the Hawaiian *Chelonia mydas* population and surrounding marine biota. This chapter investigates what plastics consist of, their inability to completely dissipate, and the chemical reactions that occur throughout its lifetime from its source to bioaccumulation in the tissues of marine species. With a definitive stance on the inner workings of the presence of plastics, it is then discussed how this material impairs the dietary and reproductive behaviors of Hawaiian *Chelonia mydas.* Chapter 3 is centered on marine ecology, gaining insights into the livelihoods of recovering Hawaiian *Chelonia mydas* populations. The effects of the ingestion of plastics, such as unnatural buoyancy, intestinal blockages, malnutrition, entanglements, and stranding are analyzed to attribute anthropogenic threats to inhibited growth rates. Chapter 4 discusses the conservation biology measures which have been taken so far to enable the recovery of the Hawaiian *Chelonia mydas*, as well as the extent to which such measures address the harmful effects of plastics pollution. Chapter 5 proposes policy recommendations to aid in the pursuit of the long-term ecological health of the Hawaiian *Chelonia mydas* and regulation of plastic pollution to preserve affected marine wildlife.

Keywords: marine ecology, environmental chemistry, conservation biology, plastic pollutants, Hawaiian *Chelonia mydas*, Hawaiian archipelago, North Pacific Ocean

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Introduction: Protecting Native Honu

The Hawaiian Islands are often associated with beautiful beaches, rich culture, and endless opportunities to engage in ecotourism. Popular activities include surfing, hiking, kayaking, mountain climbing, snorkeling, cliff-diving, skydiving, and scuba diving. Located in the North Pacific Ocean, this subtropical paradise is home to a vast array of both terrestrial and marine biodiversity. Of the most popularized and culturally significant species in Native Hawaiian Culture is the Honu, or the Hawaiian Green Turtle (*Chelonia mydas*). Hawaiian Green Turtle (*Chelonia mydas*) are the only indigenous and endemic reptile found throughout the entirety of the archipelago and symbolize the eternal link between people, the land, and the ocean. Honu has also been known to symbolize good luck and health. The patterns found on the carapace of the Hawaiian *Chelonia mydas* along with similar turtle imagery have been emulated in rock art, tapa patterns, and have ancestral ties to Native Hawaiian roots.

The Hawaiian Green Turtle (*Chelonia mydas*) has been culturally represented as a common 'aumakua or a familial guardian deity or god that provides protection and strength. Through comprehensive analysis, we understand that the scientific origins of the 'aumakua lie in the ecological protections provided to us through the Hawaiian Green Turtle (*Chelonia mydas*) role within the Archipelago's marine and terrestrial ecosystems. In Hawaiian Folklore, there is a popular children's love story that depicts a female Hawaiian Green Turtle (*Chelonia mydas*) named Honupoʻokea and her Hawksbill Turtle (*Eretmochelys imbricata*) husband, Honuʻea. Mary Kawena Pukui, a renowned Hawaiian scholar notes the tale of Kauila, the daughter of Honupoʻokea and Honuʻea. Kaulia was born on the Big Island–the geographic focal point of this thesis– within the Ka'u district of Punalu'u. Honupoʻokea came out of the ocean to lay her egg that represented the color and shape of kaulia wood. Honupoʻokea left her egg to incubate beneath the warm sand and with the help of Honupoʻokea created a freshwater pond near their daughter's nest. Honupoʻokea returned after the incubation period concluded to meet her little hatchling and care for her daughter until she was old enough to be on her own. Kauila lived at Punalu'u for the rest of her life and would often rest at the greatest depth within her pond. As she would breathe, small air bubbles would run-up to the surface and excite the local children. Kauila grew to love all the children and would often transform herself into a little girl so that she could play and protect the children on the beach. Kauila's role in society is representative of the ecosystem services provided to us by the Hawaiian Green Turtle (*Chelonia mydas*) population. The people of Ka'u were grateful for Kauila's freshwater pond as it provided clean drinking water. Hawaiian Green Turtles (*Chelonia mydas*) continue to maintain the integrity of marine water quality and much like Kauila's watchful eye all the children, Hawaiian Green Turtles (*Chelonia mydas*) provide care for all inhabitants of vulnerable coral reef populations.

Due to their migratory nature, the Hawaiian *Chelonia mydas* is often admired for its excellence in navigation. Hawaiian *Chelonia mydas* have been subjected to exploitative acts such as the over-harvesting of their eggs, consumption of their meat, loss of nesting habitats, and have been victims of bycatch. This keystone species population has consistently been classified as either 'threatened' and 'endangered' since 1978 but has yet to attain the idealistic classification of 'least concern'. Though the population has had a positive growth trend within the last few decades, it is imperative we understand what enabled the foundation of the recovery and apply this methodology to the global decline of the Cheloniidae superfamily. While the remaining 6 species are more genetically similar to each other than the Hawaiian *Chelonia mydas*, all seven known species share specific phylogenetic relationships that support the possibility of global recovery modeled off this specific population.

Throughout this thesis, we will deduce the origin of the fragility in this particular marine ecosystem and track the species population from its initial endangerment classification in 1978 to the present-day and seek feasible policy reformation to aid in the recovery of species richness and stasis of biodiversity in this marine ecosystem. The ecosystem services provided by the Hawaiian *Chelonia mydas* not only benefit dependent marine wildlife but greatly contribute to the health and wellbeing of humans, alike. Species like Hawaiian *Chelonia mydas* with a low fecundity rate inadvertently increase concern for survival. With high juvenile mortality rates, the Hawaiian *Chelonia mydas* requires particular importance in the eyes of local and federal environmental law.

The health of life-sustaining coral reefs is imperative to oceanic health and the restorative nature of the Hawaiian *Chelonia mydas*. The Hawaiian *Chelonia mydas* dietary preferences also contribute to the maintenance of seagrass beds and algal blooms. Their herbivorous tendencies result in their body fat retaining a tint of green, hence, they are often referred to as the Hawaiian Green Sea Turtle. Chapter 1 introduces quantitative data on the decline and gradual recovery of the Hawaiian Green Sea Turtle (*Chelonia mydas*). Chapters 2–4 explore the chemical, ecological, and conservation dimensions of pelagic plastics and the impending threats that further disturb the natural behaviors of the Hawaiian *Chelonia mydas.* In the final Chapter 5, I make suggestions to improve already established conservation efforts, while using the most up-to-date research to provide suggestions to strengthen the overall resilience of the Hawaiian *Chelonia mydas* population to restore its abundance.

Chapter 1: Decline of Hawaiian *Chelonia mydas*

The Hawaiian subpopulation of *Chelonia mydas* range in existence from the southeastern Hawaii Island—often referred to as the ‘Big Island’—up towards the northwestern Kure Atoll (Chaloupka and Pilcher, 2019). This particular subset of *Chelonia mydas* migrate exclusively within the Hawaiian island chain, spanning 2400 kilometers in length, and are genetically distinct from other *Chelonia mydas* subpopulations (Chaloupka and Pilcher, 2019). According to a Gompertz state-space population dynamics model that took into consideration regional ocean-climate effects driving breeding propensity over the course of 42 years, mature female nesters frequent the Northwestern Hawaiian Islands and have annually increased the population by 5.54% (Balazs and Chaloupka, 2004). While this statistic is remarkable given the high juvenile mortality rate and age range of sexual maturity falling between 30-50 years (Whittier, 2019), this steady expansion was not always the case. As of 2018, The Hawaiian *Chelonia mydas* population had been classified by the IUCN as “Least Concern”, with an increasing population trend and 6,550 mature individuals. In 2004, the IUCN classified global *Chelonia mydas* populations as “Endangered” with a decreasing population trend and an unknown number of mature individuals (Seminoff, 2004).

It is imperative to note that the Hawaiian *Chelonia mydas* provides provisionary, regulatory, habitat, and cultural ecosystem services that directly benefit humans and dependent species alike. All seven species within Cheloniidae express grazing behaviors, however, this is an attribute that is most often associated with the herbivorous *Chelonia mydas*’ maintenance of seagrass beds ("Information About Sea Turtles: Why Care?" 2020). The consumption of seagrass ensures the beds do not overgrow their desirable blade length and provide breeding grounds for smaller marine specimens such as crustaceans and fish ("Information About Sea Turtles: Why Care?" 2020). The absence of seagrass beds would impede the commercial availability of fish for human consumption, leaving these populations vulnerable and unable to reproduce, creating an imbalance in lower-level food chains ("Information About Sea Turtles: Why Care?" 2020). Humans also benefit from the *Chelonia mydas* tendency to nest on beaches, providing the needed nutrients to strengthen dunes from unhatched eggs, which in turn limits the overall susceptibility to coastal erosion ("Information About Sea Turtles: Why Care?" 2020).

The *National Climate Assessment* has indicated that the stark increase of rising sea levels, ocean acidification, and influx of warm waters resulting from climate change will disproportionately bleach corals and induce widespread disease throughout reef communities ("National Climate Assessment" 2014). Ocean acidification refers to the decrease in pH of the oceans. This decrease in pH is caused by the ocean's increased absorption rates of carbon dioxide. The more carbon dioxide we produce, the more carbon dioxide the ocean absorbs, the more acidic the water becomes. This increase in acidity weakens coral reef structures and hinders their growth, leading to stranding and habitat loss. The effects of climate change have been especially evident within the last four decades, despite the continuous warming that has taken place since 1850.

In the realms of Environmental Science and the interdisciplinary nature of Environmental Economics, the term "climate change" has become far too colloquial. Though it is understood that anthropogenic activity has served as a consistent detriment to our ecological well-being–as emphasized in both the IPCC *Climate Change 2014 Synthesis Report* and the IPCC *Summary For Policymakers*–the delay between action and consequence neglects to reinstate the importance of immediate global mitigation (Aldy *et al.,* 2009). The idea of "common but differentiated responsibilities” from the Kyoto Protocol was noted in “Designing Climate Mitigation Policy” by Joseph E. Aldy *et al.* when discussing the significance of participation delay from developing country emitters and the resulting differentiation in marginal abatement costs (Aldy *et al.,* 2009). I was reminded of our instinctive nature to avoid any means of altruism when the correlation between underlying disincentives for early developing country participation and a potential shift in global incidence abatement costs were made clear (Aldy *et al.,* 2009). If developing countries are condemned to bearing 70% of discounted abatement costs when China’s accession occurs in 2035, not only will new entrants reap the benefits of a lower starting price, but additionally, the ideal target of a 450ppm ceiling will be unachievable (Aldy *et al.,* 2009).

Geoffrey Heal touches upon the straightforward rhetoric of both accepting and assuming responsibility for the fervid constitution of climate change and the grave implications that await us (Heal, 2017). By noting inevitable food scarcity, sea-level rise, extreme weather patterns, exacerbation of widespread zoonotic diseases, and a steep decline in quality of life for humans and non-human animals alike, it seems as though the IPCC would not only deem the aforementioned repercussions as 'extremely likely' but also as a means to reevaluate our current mode of function (Heal, 2017). Apart from what would appear to be a well-deserved outcome given our consistent lack of consideration for our environment, I find the most unfortunate aspect of climate change lies in the obliteration of innocent non-human animals, flora, and fauna. The majority of plant species will be unable to adapt to stark changes in the landscape and will not be able to provide adequate nutrition or habitat for their native wildlife populations (IPCC, 2014). The Hawaiian Green Turtle (*Chelonia mydas*) requires an average annual water temperature ranging from 16ºC to 25ºC. temperature variability can drastically skew the sex ratios as noted within the next few pages and could lead to functional extinction within the archipelago. Much like the projected decline in human intelligence and cognitive function, increased extinction risks and critical endangerment of vulnerable terrestrial and marine species are guaranteed if anthropogenic development continues to propagate habitat loss (Heal, 2017; IPCC, 2014). The of the main Hawaiian Islands, Big Island has been heavily invested in coastal development which prioritizes modern infrastructure over ecological integrity. Is it right to destroy and rebuild land that is imperative to the livelihood of another keystone species? If we momentarily ponder upon the Darwinian Theory of Evolution, could it be that our interpretation of "survival of the fittest" is an all-or-nothing deal? If we cannot thrive as dominant, overbearing, and self-destructive species, would we rather have nothing at all?

If we understand that our current use of traditional fossil fuels will potentially account for three-quarters of global primary energy consumption by 2100 while the total GHG concentrations in CO_2 equivalents are projected to double pre-industrial levels at an unfathomable 550 ppm by mid-century, I cannot deduce much else apart from our secured societal and economic collapse (Aldy *et al.,* 2009). By this statistic, not only are we 29 years away from unprecedented global warming, but we would also be 20 years past the 9 year IPCC deadline of 2030, which would potentially allow us to reverse some of the known adverse effects.

With regard to the evident correlation between anthropogenic activity and depletion of natural integrity, the IPCC's "Summary for Policymakers" states the following:

> Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and

> ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen. (IPCC, 2014)

Over 90% of energy stored within the climate system is stored within the ocean warming (IPCC, 2014). Highly salinized regions such as the North Pacific Ocean have become more saline due to the overall warming catalyzing evaporation and altering the global water cycle (IPCC, 2014). If we understand that the aforementioned indirect factors ("Millenium Ecosystem Assessment" 2005) contributed toward the diminishment of global *Chelonia mydas* populations, then what aided the recovery of the Hawaiian subpopulation?

Many of the environmental deficits that contributed toward the rapid decline of this species are both abiotic and anthropogenic. Impending threats include human exploitation (Kittinger *et al.*, 2013), recreational fishing (Nitta and Henderson 1993), restricted nesting areas (Tiwari *et al.*, 2010), and ingestion of marine debris (Russell *et al.*, 2011; Nelms *et al.*, 2015). Hawaiian Green Turtle (*Chelonia mydas*) populations were subject to human exploitation for the harvesting of their eggs and the consumption of their meat (Kittinger *et al.*, 2013). This practice was primarily exercised throughout the Main Hawaiian Islands until roughly the 1970s. The effects of this exploitation were measured throughout three generations of Hawaiian *Chelonia mydas* which equates to a 100-year interval (Seminoff *et al.*, 2015) and accounted for a 20% population loss of its initial species richness.

Recreational fishing often takes all 7 species of sea turtles as accidental bycatch. Once hooked, the turtles are released alive and shortly thereafter face inevitable mortem. Necropsies were performed on 2 Hawaiian Green Turtles (*Chelonia mydas*) caught between 5.4–18.0°N and 148.5–161.3°W in the North Pacific from February 1996 through June 2000 (Work and Balazs, 2002). The results attribute the ultimate cause of death to “drowning after hooking”, indicating that the entanglements led to mild lesions accompanied by the ingestion of excessive amounts of water and abnormal dietary contents. The stomach of one of the two Hawaiian Green Turtles (*Chelonia mydas*) necropsies contained nothing but pyrosomes (Work and Balazs, 2002). This is a matter of concern, given that Hawaiian Green Turtles (*Chelonia mydas*) are herbivorous, and only display omnivorous foraging behaviors as hatchlings.

Nesting areas were primarily located in the French Frigate Shoals within the northwestern Hawaiian Islands (Frey *et al.*, 2013), however, nesting in the main Hawaiian Islands has been on the rise. The prevalence of nesting sites on the main Hawaiian Islands have been created by female nesters with a relatively rare haplotype not usually found within the French Frigate Shoals (Frey *et al.*, 2013). The 15 clutches identified throughout the main Hawaiian Islands all seem to be related to one another (Frey *et al.*, 2013), and the foundation of new rookeries allows for a feasible alternative to the northwestern Hawaiian Islands, in the event the French Frigate Shoals reach their carrying capacity.

The consumption of plastic pollutants and marine debris is not exclusively a threat to protected species like the Hawaiian Green Turtle (*Chelonia mydas*), but gravely affects all marine organisms from microscopic zooplankton to large predators (Nelms *et al.*, 2015). The ingestion of plastics can cause intestinal blockages, internal injury, dietary dilution, malnutrition, and unnatural buoyancy that often leads to stunted growth, inability to reproduce, and stranding (Nelms *et al.*, 2015). Plastic debris can cause painful lacerations, increased drag, —inhibiting the ability to fend of predation and significantly altering foraging behaviors— and altered nesting habitats (Nelms *et al.*, 2015). Some of the identified miscellaneous nonfood debris found in the digestive tracts of Hawaiian Green Turtles (*Chelonia mydas*) consisted of terrestrial leaves, plastic, paper, string, fibers, hair, and paint chips (Russell *et al.*, 2011). The presence of marine debris in nesting habitats interferes with the temperature, and therefore alters the sex ratios of the hatchlings and the overall sediment permeability (Nelms *et al.*, 2015). Prolonged exposure to marine debris could induce metabolic heating among embryos and potentially alter the overall clutch size (Önder, B. F. and Candan, 2016). There has been a strong correlation between altered nest temperature and metabolic heat creating a feminizing effect during the middle third of the incubation period when sex is determined (Önder, B. F. and Candan, 2016). With waste mismanagement as the one of the most prevalent threats to the viability of established rookeries, – in addition to the ecological harm marine species will face due to rapid climate change–it is imperative to acknowledge the need for controlled temperatures within nesting sites to avoid skewing the sex ratios of mature individuals within future Green Turtle (*Chelonia mydas*) populations (Önder, B. F. and Candan, 2016).

The highest concentration of pelagic plastic pollutants has accumulated in the convergence zones located within the subtropical latitudes (Law *et al.*, 2010). I would like to reiterate that of the seven known species of marine turtle, all are highly susceptible to the ingestion of plastics, however, the overall extent of the adverse health effects and impacts on survivorship are not well distinguished. While necropsy has proven to be effective in assessing ingestion rates of abiotic materials, there are great discrepancies in using this data to predict population ingestion trends due to the presence of impending biases between the viability of necropsies performed on stranded Cheloniidae–of which were presumably healthy at their time of death–as opposed to Cheloniidae that face death as a direct result of accidental bycatch (Casale *et al.*, 2016). If we take into consideration the overall bycatch rates among Pacific longline fisheries, we see that the Green Sea Turtles (*Chelonia mydas*) are often caught prematurely. The heightened frequency in juvenile *Chelonia mydas* mortality is due to their omnivorous diets that have yet to adapt to the herbivory displayed throughout their adult lives (Clukey *et al.*, 2017). Throughout the Green Turtle (*Chelonia mydas*) infancy through to its adolescence, these organisms feed within their natal origins of the Hawaiian island chain, specifically within the top 100 meters of the Northern islands and sometimes within the East Pacific, when juveniles are occasionally caught outside the realms of the island chain (Clukey *et al.*, 2017).

Though the kinds of plastic ingested by each species of Cheloniidae vary in overall volumes given the species-specific attributes including both life history and diet, it is understood that Green Turtles (*Chelonia mydas*) ingest roughly 70%–90% of pelagic plastic pollutants, garnering one of the highest overall frequencies among the seven species evident within the Pacific longline fisheries (Clukey *et al.*, 2017).

A study done by Wedemeyer-Strombel *et al.* in 2015 analyzed pelagic sea turtles caught in Hawaiian and American Samoan longline fisheries. Wedemeyer et. al sought to quantify the amount of plastic debris ingested over a four-year span running from 2012 through 2016. Their methodology used the following components to guide their analysis:

1. The total number of pieces, total mass, volume, and surface area, the ratio of total plastic mass to body mass, and percentage of gut contents mass consisting of plastics (Wedemeyer-Strombel *et al.*, 2015; Clukey *et al.*, 2017).
2. Assess types, colors, and locations of debris in the gastrointestinal (GI) tract (Wedemeyer-Strombel *et al.*, 2015; Clukey *et al.*, 2017).
3. Test if amounts, types, colors, and location of debris in the GI tract vary by species, capture location, season, year, turtle length, sex, and body condition (Wedemeyer-Strombel *et al.*, 2015; Clukey *et al.*, 2017).

Clukey *et al.* (2017) adapted the Wedemeyer-Strombel *et al.* (2015) study to include not only correlations with the body condition indices to investigate malnutrition as a possible sublethal impact, but further standardizes the method for quantifying plastic ingestion through the comparison of six different approaches to report the location of debris in the gastrointestinal (GI) tract. Reporting the location of plastic debris within the gastrointestinal tract allows for an estimate of the time and migration of pollution from the initial introduction to the organism's system originating from the ingestion site (Clukey *et al.*, 2017). In conjunction with the U.S. National Oceanic and Atmospheric Administration (NOAA) Pacific Island Regional Office (PIRO), the carcasses of deceased marine turtles were acquired, frozen, and prepared for necropsy (Clukey *et al.*, 2017). During the necropsy, the turtle's shell length was measured and recorded in addition to its carapace length and body condition. Body condition was classified as poor, fair, good, or excellent based on the fat and muscle quality in both the inguinal region and the beneath the plastron (Clukey *et al.*, 2017; Work, 2000). Body condition index was measured by dividing the turtle mass in kilograms by the cube of carapace length in centimeters multiplied by 100,000 (Keller *et al.*, 2014). Sex and size class were determined by the gonadal morphology and carapace length (Clukey *et al.*, 2017).

Plastics collected from the necropsies were dried overnight at room temperature and weighed to the nearest 0.00001 gram (Clukey *et al.*, 2017). The plastic fragments were classified by color and consistency, which included hard plastic fragments, flexible sheet, flexible line and/or rope, net, nurdle or pellet, width, and depth of each piece (Clukey *et al.*, 2017). The plastics collected throughout this study were evident in the esophagus, stomach, small intestine, and especially abundant within the large intestine (Clukey *et al.*, 2017). The presence of white plastics in the gastrointestinal tract outweighed all other colors and showed the Hawaiian Green Turtle (*Chelonia mydas*) to have a strong preference for soft plastics (Clukey *et al.*, 2017).

Hawaiian Green Turtles (*Chelonia mydas*) also have a distinct susceptibility to the development of Fibropapillomatosis, often referred to as 'FP', which is a debilitating disease that causes the development of benign tumors in the mouth and throat (Whittier, 2019). These tumors can severely impede feeding, breathing and/or develop on the eyes and flippers, leading to blindness and obstructed swimming habits (Whittier, 2019). Thirty-two juvenile Hawaiian Green Turtles (*Chelonia* mydas) were captured alive in Kaneohe Bay, Island of Oahu, Hawaii during September 1991 (Aguirre, 1994). Ten of the thirty-two were diagnosed with FP in varying degrees of severity (Aguirre, 1994). The virus was unable to be isolated, and the papilloma lesions were infested with other organisms, such as leeches and mites (Aguirre, 1994). Though the prevalence of FP has declined significantly in juvenile and subadult turtles (Hargrove *et al.*, 2016, Murukawa 2016), the most extreme cases can be fatal (Whittier, 2019).

Being that Fibropapillomatosis is a neoplastic disease associated with the chelonid alphaherpesvirus 5, it is often referred to as the 'ChHV5' infection (Cárdenas *et al.*, 2019). The chelonid alphaherpesvirus 5 is a double-standard linear DNA virus that is found within the *Alphaherpesvirinae* subfamily of the *Scutavirus* genus (Cárdenas *et al.*, 2019). FP has a genome size of approximately 132kb and has been reported in every Cheloniidae species within every ocean in the world (Cárdenas *et al.*, 2019; Ackermann *et al.*, 2012; Williams *et al.*, 2006). FP is most likely transmitted through the dispersal and distribution of juvenile sea turtles traveling in aggregation groups throughout ocean currents (Cárdenas *et al.*, 2019). These juvenile marine turtles inevitably come into contact with the high densities of infected turtles and exacerbate the spread of Fibropapillomatosis upon return to their natal beaches (Cárdenas *et al.*, 2019). While there are other notable hypotheses as to what propagates the spread of FP, such as horizontal transmission through direct contact with vectors including marine leeches, cleaner fish, or highly infected super spreading individuals, it is understood that the prevalence of Fibropapillomatosis is most likely correlated with the degradation of overall water quality (Cárdenas *et al.*, 2019; Work *et al.*, 2014). The aforementioned degradation of overall water quality includes changes in water temperature, an increased presence of natural biotoxins, increased arginine in the turtles' natural dietary patterns, and excessive eutrophication (Cárdenas *et al.*, 2019; Van Houtan *et al.*, 2010, 2014). The Land-based sediments and excess runoff from surrounding urban, agricultural, and industrial land uses in conjunction with other contaminants into the water lead to rising sea temperatures and ocean acidification, which in themselves are known contributors to poor water quality. The combination of these weakened environmental factors leads to increased immunosuppressants and the exacerbated expression of the Fibropapillomatosis disease (Cárdenas *et al.*, 2019; Aguirre and Lutz, 2004; Van Houtan *et al.*, 2010).

Chapter 2. Chemistry of Pelagic Plastic

In identifying the substances that constitute the structure of pelagic plastic debris found within the North Pacific Ocean, the use of Fourier-transform infrared spectroscopy, X-ray photoelectron spectroscopy, and high-temperature size-exclusion chromatography (Jung *et al.*, 2018) have been successful in determining pollution abundance. Three of the seven identified species of Cheloniidae were caught as accidental bycatch throughout local fisheries spanning the Hawaiian island chain and American Samoa (Jung *et al.*, 2018). A total of 50 specimens–37 Olive Ridley Sea Turtles (*Lepidochelys olivacea*), 9 Green Sea Turtles (*Chelonia mydas*), and 4

Loggerhead Sea Turtles (*Caretta caretta*)–were examined for the consumption of plastic materials (Jung *et al.*, 2018). While it is important to note that diving and migratory behaviors vary significantly amongst the specimens, the type of plastic ingested by each species was primarily the same. Polymers with a low density, including 51% low-density polyethylene (LPDE), 26% polypropylene (PP), in addition to 10% unknown polyethylene (PE), and 5% high-density polyethylene (PP) (Jung *et al.*, 2018) were recovered. It is important to note that hook depth, age, sex, and year did not influence the consumption of polymers (Jung *et al.*, 2018), and any deviances are exclusively spatial.

Of the aforementioned polymers, low-density polyethylene (LPDE) is produced through the polymerization of ethylene. Ethylene (C_2H_4) is a molecule with two carbon atoms and a double bond ("Making Plastics: From Monomer To Polymer" 2020), serving as the monomer for the polymerization. Polymerization is a highly exothermic reaction which requires constant cooling to inhibit the continuation of the reaction ("Making Plastics: From Monomer To Polymer" 2020). By initiating a reaction between a multitude of ethylene molecules and connecting the carbon atoms, the formation of a chain is created, and will continuously increase in molecular weight as the chain lengthens ("Making Plastics: From Monomer To Polymer" 2020).

Polypropylene (PP) is created similarly to polyethylene (PE) except for the propylene monomer and the formation of a third carbon atom molecule ("Making Plastics: From Monomer To Polymer" 2020). When in the presence of a catalyst, Propylene (C_3H_6) can uptake a variety of different physical properties including isotactic, syndiotactic, or atactic positioning in the carbon chain. Isotactic refers to the methyl (CH_3) groups aligning themselves on the centerline. The syndiotactic position of the methyl groups would appear to arrange themselves on opposite sides of the centerline. Atactic positioning is the random organization of the methyl groups anywhere on the centerline ("Making Plastics: From Monomer To Polymer" 2020).

High-density polyethylene (PP) is the linear form of polyethylene (PE) and is made by applying intense heat to petroleum. Similar to low-density polyethylene (LPDE), high-density polyethylene (PP) is produced through the polymerization of ethylene ("Poly(Ethene) (Polyethylene)" 2020). An inorganic catalyst–the most popularized catalyst used is the Ziegler-Natta catalyst in a slurry–allows hydrogen to be absorbed and attain more control of the length of the polymer chain ("Poly(Ethene) (Polyethylene)" 2020).

The abundance of pelagic plastics was last estimated to be 50 megatons in 2015 and is projected to increase to 150 megatons by 2025 (Chamas *et al.*, 2020). Degradation times vary greatly depending on the types of manufactured plastics products, their chemical compounds, and the marine environments to which they are exposed whilst residing in the ocean. Degradation takes place at the surface of the water, making the overall pelagic plastic mass loss typically proportional to the surface area of the individual piece (Chamas *et al.*, 2020). The two degradation mechanisms that we must take into consideration are the physical and chemical (Chamas *et al.*, 2020). The ‘physical’ encompasses flaking, embrittlement, and cracking from the overall macroplastic structure, while the ‘chemical’ refers to bond cleavage or the occurrence of oxidation of long polymer chains, shortening their overall length (Chamas *et al.*, 2020). With both kinds of degradation, the threat of hazards being released from soluble chemical byproducts and leaching of small molecules is of primary concern (Chamas *et al.*, 2020). In the North Pacific Ocean–more specifically, the coastal region surrounding Oahu–the average annual temperature is 78.25°F (25.7°C) as the range spans from 76°F (24.4°C) to 81°F (27.2°C) ("Water Temperature Table Of All Coastal Regions" 2018). Chemical degradation at near-ambient temperatures usually involves either hydrolysis, which requires the presence of water (H2O), or oxidation, which requires the presence of oxygen (O_2) (Chamas *et al.*, 2020). Both hydrolysis and oxidation are catalyzed by abiotic factors such as heat, light, and microbial action and ultimately mineralize the small molecules of the given plastic (Chamas *et al.*, 2020).

The structure of Polyethylene (PE) is made up of mostly C–C single bonds, therefore, these chains will not readily undergo hydrolysis and will resist photo-oxidative degradation due to the lack of UV-visible chromophores (Chamas *et al.*, 2020). Chromophores are the result of minute impurities from the manufacturing process or the effects of weathering (Chamas *et al.,* 2020). In special circumstances, the main chain or chain ends of PE may contain unsaturated C=C bonds, which is a common characteristic of vinyl in the HDPE group and vinylidene groups within LDPE (Chamas *et al.*, 2020). These double bonds are readily oxidized by tropospheric radicals such as ozone gas (O_3), and nitrogen oxide (NO_x), which become unstable hydroperoxides and become more stable UV-absorbing carbonyl groups (Chamas *et al.*, 2020). Unlike HDPE, LDPE has experienced an increased rate of photo-oxidation due to its heightened reactivity and low density, however, PE has not been able to emulate the same process (Chamas *et al.* 2020). In the absence of sunlight, the thermal oxidative degradation of PE will not occur at an accelerated rate in temperatures below 212°F (100°C) and anaerobic thermal degradation is highly unlikely to occur naturally as it requires temperatures at or greater than 662°F (350°C) (Chamas *et al.*, 2020).

It is fair to deduce that the degradation of pelagic plastics is negligible, especially concerning the decomposition of plastic products, like disposal plastic bags made from either HDPE or LDPE, in the digestive tracts of the Hawaiian Green Turtles (*Chelonia mydas*). The behavior of standard, degradable, and biodegradable plastic bags in Hawaiian Green Turtle

(*Chelonia mydas*) gastrointestinal fluids were observed over the course of 49 days (Müller, Townsend and Matschullat, 2012). The gastrointestinal fluids were collected from stomachs, small intestines, and large intestines of freshly deceased Hawaiian Green Turtles (*Chelonia mydas*) and measured against control groups consisting of salt and freshwater (Müller, Townsend, and Matschullat, 2012). The degradation rate of each plastic was measured in overall mass loss, with the biodegradable bags showing an overall mass loss between 3-9% (Müller, Townsend, and Matschullat, 2012). While the gastrointestinal fluids within the Hawaiian Green Turtles (*Chelonia mydas*) had the ability to breakdown the biodegradable polymer, the digestion rate was significantly lessened in comparison to the natural vegetative matter consumed by this species (Müller, Townsend and Matschullat, 2012). The mass loss of 3-9% is simply not enough to prevent morbidity in these animals, and certainly not enough to achieve 100% mass loss or full decomposition of biodegradable polymers within a marine or freshwater system (Müller, Townsend and Matschullat, 2012).

Chapter 3. Inhibiting Ecology and Evolution

The subtropical North Pacific Ocean is arguably 'homogeneous' regarding its physical and biological properties (Campbell *et al.*, 1997). The North Pacific Subtropical Gyre (NPSG) is one of the five major ocean gyres, gaining momentum through rotating ocean currents fluctuating in a clockwise motion in the northern hemisphere, and counterclockwise in the southern hemisphere due to the Coriolis effect. The NPSG has accumulated a plethora of floating marine debris and is home to the infamous what is often referred to as the 'Great Pacific Garbage Patch, or in reality a concentrated gyre of microplastics within the greater North Pacific

Subtropical Gyre. The marine debris contains fragments of plastics and increases in volume due to the vortex-like nature of the subtropical convergence zone (National Geographic Society, 2012). The main kinds of plastic products are unrecognizable with exception of some identifiable characteristics–in the case of macrodebris, 50% is presumed to be sourced from fishing floats or buoys–that indicate either its terrestrial or aquatic use ("Plastics At SEA North Pacific Expedition–Investigating The Effects Of Plastic In The Ocean Ecosystem | Home", 2012). The main sources of marine debris enter the NPSG from intentional and unintentional dumping from vessels at sea, lost shipping containers, lost recreational fishing and/or aquaculture gear ("Plastics At SEA North Pacific Expedition - Investigating The Effects Of Plastic In The Ocean Ecosystem | Home", 2012). Without the ability to identify the definitive sources of input, the postponement of environmental policy amendments will prevail.

While the garbage patch is in fact two separate entities, the western garbage patch and the eastern patch–usually referred to as the ‘North Pacific Subtropical High’–this paper focuses on the eastern patch and its effects on the marine species that inhabit the Hawaiian archipelago. The currents that make up this swirling roasting of debris include the California Current, the North Equatorial Current, the Kuroshio Current and the North Pacific Current (National Geographic Society, 2012).

While the center of the gyre is quite tranquil, the vast circular currents attract all the encompassing debris towards its center, leaving it trapped (National Geographic Society, 2012). The entrapment is also catalyzed by the material’s inability to biodegrade. Consider that the majority of the litter found in these patches is plastic or a plastic derivative. Plastic water bottles have a lifespan of 450 years, and even so, the decomposition process can further postpone its degradation (National Geographic Society, 2012).

Of the pollutants evident in North Pacific, the chemical concentrations of different types and sizes of plastics have been assessed concerning detriment potential in decreased sediment quality criterion given the bioaccumulation of abiotic materials (Chen *et al.*, 2017). Of the buoyant plastics present within the North Pacific Ocean, persistent bioaccumulative toxic chemicals (PBT) including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and nonylphenol (NP) have diminished the strength of overall ecological marine health (Chen *et al.*, 2017). Persistent bioaccumulative toxic chemicals are evident within the North Pacific Subtropical Gyre due to the flame retardant properties and sorption to plastics from the marine environment through partitioning mechanisms (Chen *et al.*, 2017). Though the use of the popular PBTs such as Chlordane was banned in the United States in 1988, the following PBTs are still in use statewide:

- Decabromodiphenyl ether (decaBDE), or ($C_{12}Br_{10}O$), is used as an additive flame retardant for plastics, polymers, composites and is widely used in the textile industry (*D* (European Chemicals Agency, 2013). Unlike reactive flame retardants, Decabromodiphenyl ether (decaBDE) is a general-purpose flame retardant and therefore not chemically bound to the base material as it is physically incorporated (European Chemicals Agency, 2013). Decabromodiphenyl ether (decaBDE) evident in plastics and polymers makes up approximately 10%–15% of the weight of the item and has reported usage loading requirements of nearly 20% (*D* (European Chemicals Agency, 2013). Decabromodiphenyl ether (decaBDE) tends to absorb quickly into organic materials such as soil, sediment, and sewage sludge (European Chemicals Agency, 2013). The substance itself has a low water solubility and significantly limits the mobility of the organic matter throughout its steady state and will release its emissions throughout the entirety of its lifetime (European Chemicals Agency, 2013).

- Phenol isopropylated phosphate (3:1), also known as PIP (3:1), is used as a flame retardant in consumer products, and serves as a popular industrial lubricant and hydraulic fluid. The European Chemical Agency has noted that this substance is not only highly toxic to aquatic life but is also known to cause compromised fertility rates and organ damage in humans ("Phenol, isopropylated, phosphate (3:1) - Substance Information - ECHA", 2021). This substance is often released into the environment through industrial use and found in almost all household materials ("Phenol, isopropylated, phosphate (3:1) - Substance Information - ECHA", 2021).
- 2,4,6-tris(tert-butyl) phenol (2,4,6-TTBP), or ($C_{18}H_{30}O$) is a lubricant additive in automobile and jet fuels (Environmental Protection Agency, 2017). The EPA notes that the exposure scenarios for this chemical are not well researched, therefore, adequate risk assessments have yet to be conducted (Environmental Protection Agency, 2017).
- Pentachlorothiophenol (PCTP), or (C_6HCl_5S), is used to make rubber more pliable as it is slightly soluble in water (National Center for Biotechnology Information, 2021). Pentachlorothiophenol (PCTP) is known to breakdown quintozene and hexachlorobenzene in soil (National Center for Biotechnology Information, 2021). The health risks associated with exposure to this chemical have yet to be researched (National Center for Biotechnology Information, 2021).
- Hexachlorobutadiene (HCBD), or (C4Cl6) is used as a solvent, hydraulic, heat transfer, or transformer fluid and is often found in rubber compounds ("US EPA Proposes Partial Bans On Four Pbts"; "Hexachlorobutadiene", 2021). Hexachlorobutadiene (HCBD) is not

found naturally within the environment and is not only insoluble in water but also denser than water itself ("Hexachlorobutadiene", 2021). While the health effects of long-term exposure to Hexachlorobutadiene (HCBD) have not been assessed animals have been known to develop kidney tumors, degradation of the respiratory system, in addition to a reduction in fetal body weights ("Hexachlorobutadiene", 2021). The EPA has acknowledged that Hexachlorobutadiene (HCBD) may be a possible human carcinogen ("Hexachlorobutadiene", 2021).

The Chen *et al.* study notes the prevalence of PBTs in marine contaminations and states that "the environmental chemistry and toxicological hazard of ocean plastic-associated chemicals are still poorly understood." (Chen *et al.*, 2017). Their results suggested that plastic-bound and sediment organic matter-bound PBTs have similar partition coefficients, desorption half-lives, and exposure pathways, with least a fraction of the aforementioned plastics not in equilibrium with the surrounding seawater (Chen *et al.*, 2017).

In an attempt to understand the effects of pelagic plastic accumulation, Peter Davidson dissected a total of 141 fish from 27 species to examine what the contents were in the stomachs of the organisms (Davidson *et al.*, 2011). He was able to determine that the ingestion rate of plastic debris by mesopelagic fish in the north pacific is estimated to be from 12000 to 24000 tons annually. (Davidson *et al.*, 2011). If the Eastern Garbage patch contains 20,240 tons of plastic, does this mean the pelagic plastic will never be able to truly dissipate from the Eastern Garbage patch (Sesini, 2011)?

The Hawaiian Islands are at risk for inundation due to the surrounding ground and surface waters (Nelson *et al.*, 2011). Oahu, Hawaii has faced the effects of climate change, soil thickness, and water contact (Nelson *et al.*, 2011). Basalt serves as the dominant bedrock of

Oahu and has shown evidence of weather-driven chemical erosion (Nelson *et al.*, 2011). Components that greatly impact this island include rainfall and water-rock contact time (Nelson *et al.*, 2011). The rainfall in Oahu varies by magnitude, and the weathering reaction that follows suit greatly impacts the minerals present in native Oahu soils (Nelson *et al.*, 2011). The mineralogical impact is of particular importance, given that Hawaiian Green Turtles (*Chelonia mydas*) are known to nest on Laniakea Beach.

The Hawaiian Islands are found within the subtidal and intertidal coral and seagrass meadows available in the continental shelf which allows Laniakea Beach to attract sub-adult and adult Hawaiian Green Turtles (*Chelonia mydas*) (Houtan, 2015) due to the presence of algae, seagrass, jellyfish, and mangrove fruit ("Marine Turtles."). This area plays a critical role during late October running through February when breeding season is in full effect. Laniakea's location on the North shore of Oahu serves as a foraging and basking area for the Hawaiian Green Turtles (*Chelonia* mydas) and is the base point for seasonal breeding migration to and from the French Frigate Shoals in the Northwestern Hawaiian Islands (Rice and Balazs, 2008). Rice and Balazs tagged three Hawaiian Green Turtles (*Chelonia mydas*)–one female and two males–and noted that the 800–1100km trip takes approximately 20 to 50 days to complete (Rice and Balazs, 2008). The diel diving patterns of the Green Turtle (*Chelonia mydas*) are known to vary throughout the migration, with depths of each dive often exceeding an excess of 120 meters (Rice and Balazs, 2008). The dives were classified into four distinct categories: Type 1, Type 2, Type 3, and Type 4. Type 1 dives were typically shallow as they were no deeper than 5 meters (Rice and Balazs, 2008). Type 2 dives were greater than 5 meters in-depth and no longer than 10 minutes in total length (Rice and Balazs, 2008). The characteristics of a Type 2 dive have a steep descent to designated depth with a gradual ascent back to the surface (Rice and Balazs, 2008).

Though the criterion of Type 3 dives is similar to Type 2 in that the dive is deeper than 5 meters and longer than 10 minutes in length, the initial descent is at a much greater depth with a rapid ascent that transitions into a gradual ascent (Rice and Balazs, 2008). Type 3 dives were the most common among the nocturnal diving phase that was observed among the three individuals. The condition in which the Type 3 dive is applied constitutes the 'deepwater phase' of migration (Rice and Balazs, 2008). Type 4 dives are regarded as 'U-shaped' dives that are greater than 5 meters with 90% of the bottom time spent at the maximum depth (Rice and Balazs, 2008). Type 4 dives are resting dives. Rice and Balazs note the first three dive types to be the most probable dives to be observed within the pelagic environment (Rice and Balazs, 2008). The satellites were removed once the turtles returned to Laniakea to bask in the sun (Rice and Balazs, 2008). With nocturnal dive depths exceeding 120 meters–previously, dive depths exceeding 200 meters had only been recorded in a laboratory–and shallow dive depths occurring during daylight, it is possible to attribute this behavior to the use of sun compass navigation (Rice and Balazs, 2008). Type 3 dives allude to the 3 Green Turtles (*Chelonia mydas*) displaying similar dives to Green Turtles resting on seabeds, indicating that rapid movement most likely occurs during the daytime when breeding migrations are most active (Rice and Balazs, 2008). The depths and lengths of each kind of dive may also vary due to the Green Turtle’s (*Chelonia mydas*) use of currents to help direct them toward their ultimate destination when leaving and returning to their natal beaches (Rice and Balazs, 2008).

The overall proportion of the Green Turtle (*Chelonia mydas*) population is the only species of marine turtle that is strongly influenced by the El Niño Southern Oscillation (ENSO) Index (“Marine Turtles.”). This correlation occurs due to the dietary needs of this species. The nesting and foraging habits of the Green Turtle (*Chelonia mydas*) influence its migration patterns. These migratory patterns play a significant role in the sustenance of long-term hexacoral and octocoral health and surrounding marine biota.

Hexacorals are hard corals that can be further distinguished into two separate categories: zooxanthellate corals and azooxanthellate corals. Zooxanthellate corals are hermatypic, or reef-building corals that depend on zooxanthellae algae to provide nutrients (Bauer, n.d.). These corals prefer to lie in shallow water no deeper than approximately 50 meters deep. The algae which they eat is entirely dependent on the sunlight (Bauer, n.d.). Azooxanthellate corals are ahermatypic, deep water corals that have no zooxanthellae to feed on (Bauer, n.d.). The azooxanthellate corals garner their nutrition through filtering plankton from the surrounding seawater. These corals tend to be isolated and rarely develop into large communities (Bauer, n.d.). Many azooxanthellate coral species are also present in non-reef environments near coastal areas (Devantier *et al.*, 2006).

With regard to Octocorals, ⅓ of the world's soft corals including sea pens (*Pennatulacea*), blue corals (*Heliopora coerulea*), and sea fans (*Alcyonacea*) are native to the Great Barrier Reef (Bauer, n.d.). These corals have a flexible, even sometimes "leathery" appearance. Soft corals are colonial organisms meaning they are formed by colonies of polyps (Baird and Marshall, 2002). The polyps of soft corals have eight feather-like tentacles, hence the reason they are known as octocorals (Baird and Marshall, 2002). To differentiate between soft corals and hard corals, one should carefully observe the polyps. The polyps of hard corals have six tentacles that resemble stone as opposed to the feathery-like polyps of the soft corals (Baird and Marshall, 2002).

With coral species, it is extremely important to consider the last five mass extinctions that have occurred throughout the last half-billion years. Each extinction has greatly devastated the viable, somewhat untouched colonies. Each extinction has increased in severity and lessened the ability to recuperate large coral communities. The fecundity of coral is quite high; however, we must note that the regeneration of an impacted colony is extremely gradual. Corals tend to take thousands of years to reach their larval stage and are incredibly sensitive to their surrounding environments. Within *Living In The Environment*, Chapter 11 titled, "Sustaining Aquatic Biodiversity and Ecosystem Services" states:

> If given enough time, many species of corals can adapt to changes in environmental conditions such as warmer and perhaps more acidic water. However, corals are threatened with rapidly rising water temperatures, acidity, and sea levels during this century, which will not give them enough time for adaptation. (Miller and Spoolman)

Adaptation can also be skewed by unsustainable practices employed for seafood markets, urban/coastal development and dredging (Miller and Spoolman). The destruction of ocean-bottom habitats is almost irreparable. Azooxanthellate coral prefers low-light environments and cannot rely on phytoplankton for long-term survival. Any disturbance to azooxanthellate corals not only affects the coral's polyps but also hurts the inhabitants' populations. Without a place to migrate, these vulnerable creatures could be left without a place to live and will be driven to extinction. The inter-specific and intra-specific competition would be heightened and lead toward an unmanageable disruption of marine food webs.

The extinction of a species requires decomposition which leads to the depletion of oxygen levels that aquatic life relies on. With low oxygen levels, suffocation occurs should the marine species not be able to source oxygen from elsewhere. Though these events may seem small, the entirety of the food web is negatively affected. Top predator fish like sharks, tilefish, swordfish, king mackerel, and white tuna accumulate high levels of mercury (Miller and

Spoolman). Top predator fish are often highly popularized within the seafood market. Ingesting high levels of mercury can seriously harm the brain, heart, kidneys, and even the immune system. If the impact is incredibly harmful on humans, could you even consider what effects the bioaccumulation of mercury could have on aquatic life that is fighting for their survival?

Chapter 4. From 'Endangered' to 'Least Concern'

Within the Hawaii Revised Statutes (HAR) (Chapter 195D), general provisions and recovery initiatives including but not limited to the implementation of conservation programs, enforcement, habitat conservation plans, and endangered species recovery are detailed to ensure the ecological health of all aquatic life, wildlife, and land plants. Cheloniidae are also protected by state and federal law. With regard to this specific chapter within the HAR, the Attorney General states:

> Threatened and endangered plants are protected on Hawaiian homelands under the provisions of this chapter, as well as under the provisions of the federal Endangered Species Act of 1973, to the same extent that the plants are protected elsewhere in Hawaii. Anyone who "takes" threatened or endangered plants on Hawaiian homelands is subject to state and federal civil and criminal penalties. ("CHAPTER 195D CONSERVATION OF AQUATIC LIFE, WILDLIFE, AND LAND PLANTS" 2020)

The criminal penalties one could be subjected to for taking native plants or animals stand true concerning the Green Turtle (*Chelonia* mydas) and other endemic species protected under federal legislation and Hawaiian State law (Chaloupka and Pilcher, 2019). HAR Chapter 195D-9 notes that the violation of any provision within the chapter will be guilty of a misdemeanor and punished by the following:

> (1) For a first offense by a fine of not less than $250 or by imprisonment of not more than one year, or both; and
>
> (2) For a second or subsequent offense within five years of a previous conviction by a fine of not less than $500 or by imprisonment of not more than one year, or both. ("HI - Endangered Species - Chapter 195D. Conservation of Aquatic Life, Wildlife, and Land Plants | Animal Legal & Historical Center", 2020)

HAR 195D-9 also highlights the violations with regard to the habitat conservation plans under section 195D-21 and the safe harbor agreements under section 195D-22. Throughout the Hawaiian archipelago, there are fines for touching or harassing marine mammals, such as the $5,000.00 USD fine for any individual threatened species and $10,000.00 USD fine for the intentional or unintentional harm defined by death or removal of an endangered species from its natural habitat ("HI - Endangered Species - Chapter 195D. Conservation of Aquatic Life, Wildlife, and Land Plants | Animal Legal & Historical Center", 2020). Any kind of violation of the Endangered Species Act, including both the aforementioned actions in addition to the pursuit, capture, injury, or death of a protected animal is considered a federal crime ("Men Fined For Capturing A Hawaiian Green Sea Turtle", 2017). NOAA Fisheries state that:

> ... an ESA violation can incur much more significant penalties depending on the severity of the violation or degree of taking: Civil penalties can exceed $50,000 and Criminal penalties can include fines of up to $100,000 and imprisonment of up to one year. ("Men Fined For Capturing A Hawaiian Green Sea Turtle" 2017)

The Green Turtle (*Chelonia mydas*) is not only protected under the Endangered Species Act, but it is protected under the Marine Mammal Protection Act and Hawaii state laws. The Hawaii state laws that protect the Green Turtle (*Chelonia mydas*) are the aforementioned Hawai'i Revised Statutes (Chapter 195D) and Hawai'i Administrative Rules (13-124). Hawai'i Administrative Rules (13-124) indicates that:

> ...no person shall or attempt to: (1) Take, possess, process, sell, offer for sale, or transport any such species, any young or egg, or the dead body or skin thereof within the State; ... (c) No person shall remove, damage, or disturb the nest of any indigenous, endangered, or threatened species except as provided in subsection. (*CHAPTER 124 INDIGENOUS WILDLIFE, ENDANGERED AND THREATENED WILDLIFE, AND INTRODUCED WILD BIRDS*, 2013)

Similar to the Endangered Species Act, Hawaii has its own set of policies that prohibit the infliction of harm on the Green Turtle (*Chelonia mydas*) and other native species. No amendments have been proposed since the enactment of this rule in 2013. Exploitative ecotourism is the most frequent culprit of violations of the above-noted laws. While the state recommends a 6–10-foot distance when observing Hawaiian Green Turtles (*Chelonia mydas*), there is no structure in place to enforce this suggestion. While *Chelonia mydas* are docile creatures by nature, they can exhibit aggression when their dietary habits are disturbed.

In 1974, the Hawaiian Green Sea Turtle was listed under State Division of Fish and Game Regulation 36 and listed under the Endangered Species Act four years later in 1978 (Chaloupka and Pilcher, 2019). The *Chelonia mydas* status of full protection under Hawaii State list of wildlife under Chapter 194 was equivalent to the Endangered Species Act protection it had been granted when listed in 1978 (Chaloupka and Pilcher, 2019). The French Frigate Shoals located in the Northwestern Hawaiian Islands– regarded as the main rookery during the migratory breeding season from Laniakea Beach–are also protected due to the Papahānaumokuākea Marine National Monument (Chaloupka and Pilcher, 2019). The Papahānaumokuākea Marine National Monument spans over 582,578 square miles of the Pacific Ocean, or 1,508,870 square kilometers ("About Papahānaumokuākea", n.d.). The monument's boundaries encompass 10 of the Northwestern Hawaiian Islands and allow the (*Chelonia mydas*) nests on the French Frigate shoals to benefit from its federal and state protection privileges (Chaloupka and Pilcher, 2019). The Papahānaumokuākea Marine National Monument is not only the largest fully protected conservation area within the United States and one of the largest marine conservation reserves in the world, but it is also considered a UNESCO World Heritage site ("About Papahānaumokuākea", n.d.; Chaloupka and Pilcher, 2019). A UNESCO World Heritage Convention is selected by the IUCN, ICOMOS, and ICCROM based on the following criteria:

> (vii) to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;
>
> (viii) to be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features;
>
> (ix) to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals;
>
> (x) to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding

> universal value from the point of view of science or conservation. ("World Heritage Convention", n.d.)

The IUCN has noted that the Hawaii-based longline fishery's efforts in reducing accidental bycatch significantly contributed to the recovery of this endemic subpopulation. The establishment of the longline protected species zone prohibited pelagic longline fishing near designated islands and atolls to prevent monk seals from fatal vessel strikes (Chaloupka and Pilcher, 2019). This protection for the monk seals provided equal benefits to the Hawaiian Green Turtle (*Chelonia mydas*) population (Chaloupka and Pilcher, 2019). A recent update to enhance this protection includes the mandatory use of circle hooks, mackerel-type bait, and an annual attendance of protected species workshops for all longline fishery employees (Chaloupka and Pilcher, 2019). These workshops go over proper turtle handling techniques to adequately assess injured specimens, dehook turtles who have faced accidental bycatch, and the procedure to revive comatose turtles (Chaloupka and Pilcher, 2019). The noted actions have helped reduce cases of accidental bycatch by nearly 90% (Chaloupka and Pilcher, 2019; Gilman *et al*. 2007). This is 90% is based on both shallow-set fishery and observer coverage in the deep-set fishery (Chaloupka and Pilcher, 2019).

Consider that the implementation of the most active and effective conservation biology initiatives start at the local level. The Surfrider Foundation Oahu Chapter has dedicated themselves to the protection and enjoyment of the world's ocean, waves, and beaches, for all people, through a powerful activist network ("Mission", 2020). The Surfrider Foundation fights for ocean protection, the reduction of plastic pollutants on marine environments, fair beach access, coastal preservation, and protection of clean water. Through volunteer opportunities and campaigns, The Surfrider Foundation has been successful in bringing awareness to environmental issues concerning the ocean and fundraising to implement an environmental policy and fight legal battles to protect vulnerable marine and wildlife ("Mission", 2020). Through a shared platform, awareness concerning the *Chelonia mydas* has been brought to fruition, detailing the impacts of Kahuku Beach, Oahu. Kahuku Beach is colloquially referred to as 'Oahu's Plastic beach', as it is littered with fishing gear, ropes, buoys, and polystyrene foam, plastic bags, plastic films, water bottles, and millions of fragmented plastic pieces ("Do You Like Sea Turtles?", 2020). Of the abundant pelagic plastic pollutants, samples from Kahuku Beach taken in October and November of 2014 suggest that the most common plastics were white particles that represented 5.9% of the 44.988 particles obtained from the collection site (Young and Elliot, 2016). The Surfrider Foundation also played a significant role in implementing the plastic ban in Hawaii, a policy we will thoroughly examine in the following chapter.

Sustainable Coastlines Hawaii was founded in 2010 and conducts beach cleanups to inspire eco-conscious consumer behavior, coastal stewardship, and environmental education ("About Us | Sustainable Coastlines", 2020). Sustainable Coastlines Hawaii focuses on solving the marine debris issue in Oahu and uses the plastic collected at their beach cleanups to create sustainable products. The plastic pieces are sorted out from other debris items and recycled into soap dispensers and skateboard decks ("About Us | Sustainable Coastlines", 2020). As of now, Sustainable Coastlines Hawaii has successfully recycled 27.500 pounds of plastics ("About Us | Sustainable Coastlines", 2020). By cleaning up plastic debris from Hawaiian Green Turtle (*Chelonia mydas*) nesting sites, the juvenile mortality rate is significantly lessened, allowing more hatchlings to survive.

B.E.A.C.H.–which stands for Beach Environmental Awareness Campaign Hawaii–is a volunteer-run, non-profit that provides solutions for marine debris removal, research, plastic reduction, litter prevention campaigns, and brings awareness to the importance of environmental education ("Beach Environmental Awareness Campaign Hawai`i: Marine Debris", 2020). B.E.A.C.H. deals primarily with pelagic plastics from the NPSG, which is the Great Pacific Garbage Patch noted in Chapter 2. This organization places emphasis on the aftermath of plastic ingestion in both the Chelonia mydas and Albatross chicks, both of whom mistake plastic pollutants for food. Volunteers are encouraged to document their fieldwork through photographs and take water samples to identify the origins of plastic fragments. Furthermore, B.E.A.C.H. allows volunteers to help rehabilitate Chelonia mydas and other indigenous wildlife from entanglement injuries and restore habitat destruction ("Beach Environmental Awareness Campaign Hawai`i: Marine Debris", 2020). Citizen science is crucial to the fair assessment of both qualitative and quantitative data.

The conservation of native biodiversity is crucial to the Hawaiian Archipelago, as the native wildlife is genetically isolated and from any other species within its taxa and endemic to the geographic region. In 2010, 317 taxa of plants and animals listed by the U.S. Fish and Wildlife Service (USFWS) as endangered or threatened, 12 taxa proposed as endangered, and 105 taxa as candidates for listing (Hawaii Statewide Assessment of Forest Conditions and Resource Strategy, 2010). As of 2005, Congress required the Comprehensive Wildlife Conservation Strategy to be updated every five years to upkeep with the wide variety of indigenous wildlife (Hawaii Statewide Assessment of Forest Conditions and Resource Strategy, 2010). The interconnectivity of local activities such as surfing, snorkeling, fishing, and hiking are all significantly enhanced by the presence of native wildlife, all of which make up the unique ecosystems present amongst each of the individual islands (Hawaii Statewide Assessment of Forest Conditions and Resource Strategy, 2010).

Chapter 5. Preservation through Policy

Throughout this thesis, we have addressed the anthropogenic factors that led to the initial decline and IUCN classified endangerment of the Hawaiian *Chelonia mydas* population and the abiotic threats that have artificially altered their natural behavior. With an understanding of the impending threats of exacerbated climate change, in addition to ocean acidification, coral bleaching, and sea-level rise, the environmental deficits that are a consequence of human activity must be halted. The continued demand for modern infrastructure and endorsement of manufacturing companies using illicit, unsustainable practices to appease consumers endorses the increased abundance of marine debris within the North Pacific Ocean, impeding the health of not only affected marine species but the ecosystem services derived from their existence. With natural habitats of marine and terrestrial animals becoming smaller and more impacted by pollution, there is a clear need to look into policies that can conserve the habitats of already vulnerable organisms to ensure their longevity and survivorship for future generations undisturbed growth. When considering methodologies that take into account the adequate conservation of animals with the protection of local economies mutually benefiting one another simultaneously it is crucial to note that the attainment of effective policy should not come at the complete detriment of the other participant. The key to long-term ecological viability with minimal externalities lies in the following question: What policy will most effectively improve the natural habitat of the endangered Hawaiian Green sea Turtle (*Chelonia mydas*) in Oahu, HI, while also protecting the economy of local, underrepresented Indigenous communities? Any policy enacted to protect a specific environment will cause impact upon the local economies – it may be a tax that causes a loss of tourism, a ban that costs money to implement, or any number of other things. The policy enacted must balance the cost-benefit and determine the optimal level of change. I believe waste management, public education, and conservation should be prioritized to further improve upon established conservation efforts and strengthen the overall resilience of the Hawaiian *Chelonia mydas* population.

Waste Management. Chapter 2, "Chemistry of Pelagic Plastic" detailed the severity of the overabundance of marine debris and the environmental hazards faced by affected marine biota due to the gradual degradation processes. On December 4th of 2019, Honolulu City Council passed Bill 40 with a vote of 7-2 (*Bill 40 (2019), CD1, FD1* 2019). This bill redefined "plastic" as, "any material made of fossil fuel-derived or petrochemical polymeric compounds and additives that can be shaped by flow." (*Bill 40 (2019), CD1, FD1* 2019).

In its ordinance, Bill 40 notes the need for reassessed environmental policy and notes the following concerning impacted ecological well-being of the archipelago as a whole:

> Single-use plastic service ware and packaging are major contributors to street and beach litter, ocean pollution, harm to marine and other wildlife, and greenhouse gas emissions, which directly contribute to the global climate crisis. A significant portion of marine debris --estimated to be 80 percent-- originates on land, primarily as escaped refuse and litter, much of it plastic, in urban runoff. These land-based plastics degrade into pieces and particles of all sizes, including microplastics, and are present in the world's oceans at all trophic levels. (*Bill 40 (2019), CD1, FD1* 2019)

Bill 40 promises to phase out single-use plastics and ban all takeout plastics over the course of two years. It will be effective as of January 2021 and will allow businesses a one-year grace period to come into full compliance with the ban by January 1, 2022. While this is one of the most innovative–and albeit strict–laws enforcing the need to move off an oil-dependent economy, I believe that a stronger emphasis must be placed on the proper disposal of these plastic products. Nowhere in Bill 40 is there an annotation to include a feasible solution toward eliminating harm imposed on marine biota and other wildlife. While the rigor of this bill is up to par, and the desired outcomes are certainly feasible, Bill 40 is a humanist bill concerning itself with the anthropocentric implications as opposed to satiating the environmental injustices faced by all human and non-human members of the Hawaiian Island chain. As mentioned in Chapter 3, "Inhibiting Ecology and Evolution", the issue of pelagic plastics lies in the overarching inability to identify where the pollutants have been sourced from and which parties would be held accountable.

While it is well-established that the Hawaiian Green Sea Turtle (*Chelonia mydas*) is particularly threatened by overharvesting of their eggs, hunting of adults, being caught in fishing gear and loss of nesting beach sites, one issue of serious concern is the consumption of plastic. Plastic has been mass produced since the 1940s, but only recently have we come to understand its devastating impact on all seven species of turtle sin the Cheloniidae superfamily. The ingestion of any abiotic material can be fatal, yet the North Pacific Subtropical Gyre is littered with micro and macro debris with no single entity responsible for the decades-worth of global environmental disregard. The ingestion of sharp plastics can rupture internal organs, and single-use plastic bags can cause intestinal blockages leaving the turtles unable to feed, and ultimately terminate their lives prematurely due to starvation and or asphyxiation. In the rare event that the turtle survives the increasingly alarming rates of plastic consumption, the plastic can result in the turtles becoming unnaturally buoyant. This newfound buoyancy stunts the growth of the organism and can lead to long-term deceleration of reproductive rates. This deceleration would almost certainly guarantee the extinction of the Green Turtle (*Chelonia mydas*) and Hawaiian Green Turtle (*Chelonia mydas*) entirely.

Public Education. As noted in chapters 1 and 3, the well-being of the Chelonia mydas is vital to surrounding marine biota and humans alike. Bill 40 was implemented largely due to the support of the Surfrider Foundation Oahu Chapter, along with non-profits including Zero Waste Oahu, Sustainable Coastlines Hawaii, Sierra Club Oahu, Kokua Hawaii Foundation, B.E.A.C.H., and Sustainable Island Products. By making environmental science and environmental education more widespread, the ability to enforce environmental policy is simple. By holding one another accountable for an equal contribution to an environmentally sound ecosystem, we eliminate the alienation of non-human animals and their intrinsic right to quality of life.

Since its initial implementation, Bill 40 has had four successful amendments including Chapter 9, Article 9, Ordinance 12-8, Ordinance 14-29, and Ordinance 17-37. Made effective July 1, 2015, Chapter 9, Article 9 Discusses the Regulation of Bags Provided to Customers. The four sections within the article provide clarifications with regard to defining the delineations between compostable plastic bags–meant for reuse, meeting the Biodegradable Product Institute ("BPI") standards– and plastic checkout bags not intended for reuse (*Article 9. Regulation of Bags Provided to Customers**, 2015). Ordinance 12-8, as well as Ordinance 14-29, were also put into effect on July 1, 2015. The purpose of Ordinance 12-8 was to regulate the consumer use of non-biodegradable plastic bags (*Ordinance 12–8*, 2015). The council findings note the EPA's acknowledgment of plastics making up more than 12.4% of the total tonnage of municipal waste from the 31 million tons of plastic waste generated (*Ordinance 12–8*, 2015). Ordinance 12–8 noted that before 2015, Honolulu was the only Hawaiian county without regulation the distribution of plastic bags used in point-of-sale purchases. Ordinance 12–8 correlated pervasive plastic use with the potential increase in marine animal mortality rates and goes so far as to explicitly state the increased cost of non-biodegradable plastic production and the prolonged delay in decomposition after disposal (*Ordinance 12–8*, 2015). Businesses from 2015 onward were required to provide an eco-conscious alternative to plastic bags to allow their customers to take their goods home, free of charge (*Ordinance 12–8*, 2015).

Ordinance 14–29 further elaborates on the issues brought forth by Ordinance 12–8, however, Ordinance 14–19 discusses the adverse effects certain kinds of plastic bags have on the environment and the impending health risks associated with unintentional ingestion by non-human animals (*Ordinance 14–19*, 2015). The definition of "biodegradable" outlined in Ordinance 12–8 states “Biodegradable means a substance that can be broken down in the environment by natural processes." (*Ordinance 14–19*, 2015). The Department of Environmental Services in Honolulu, Hawaii was unable to find an industry standard that was able to meet the needs of state guidelines, therefore, they turned to independent entities such as the Biodegradable Institute (*Ordinance 14–19*, 2015). The Biodegradable Institute has a certification program that tests products for quick and safe degradation rates within composting facilities. By stamping approved products with a highly visible green logo, not only are businesses given more options within their budget constraints, but consumers can positively impact the environment by minimizing their ecological footprint without significantly altering their lifestyles (*Ordinance 14–19*, 2015). Ordinance 14–19 goes on to redefine "biodegradable" and "non-biodegradable", in addition to compostable plastic bags in contrast to plastic checkout bags:

> [“Biodegradable” means a substance that can be broken down in the environment by natural processes.”]

> [“Non-biodegradable” means a substance that cannot be broken down in the environment by natural processes.”]
>
> “Compostable plastic bag” means a checkout bag that is provided to a customer for the purpose of transporting groceries or other retail goods, that meets current ASTM D6400 Standard Specifications for compostability and that is labeled:
>
> 1) With the Biodegradable Product Institute (“BPI”) logo as meeting the ASTM standard for compostability; and
> 2) With “Compostable” on both sides of the bag in either green color lettering that is at least one inch in height, or as otherwise specified; or within a green color band that is at least one inch in height in order to be readily and easily identifiable.”
>
> “Plastic checkout bag[:]”:
>
> (1) Means a [bag that is made from non-biodegradable plastic, and is] carryout bag that is provided by a business to a customer for the purpose of transporting groceries or other retail goods, and is made from non-compostable plastic and not specifically designed and manufactured for multiple re-use. (*Ordinance 14–19*, 2015)

Ordinance 17–39 section 2 was a revised ordinance on the definition of a "plastic checkout bag", and the implication with regard to its use effective on January 1 of 2020. As of the publication of this thesis, The State of Hawaii has defined the plastic checkout bag as:

> a carryout bag that is provided by a business to a customer for the purpose of transporting groceries or other retail goods and is made from [non-compostable] plastic and not specifically designed and manufactured for multiple re-use. (*Ordinance 17–39*, 2017)

Sections 3 through 5 of Ordinance 17–39 took effect on July 1, 2018, and specified the uses of plastic film bags, reusable bags, bans on plastic checkout bags, and non-recyclable paper bags (*Ordinance 17–39*, 2017). Section 6 of this ordinance notified the Hawaiian public of the discontinuation of compostable plastic bags being to consumers during point-of-sale services (*Ordinance 17–39*, 2017).

Conservation. In chapter 4, "From 'Endangered' to 'Least Concern'", the Hawaii Revised Statutes (HAR) (Chapter 195D) are noted for the general provisions and recovery initiatives which serve to implement conservation programs, enforcement, habitat conservation plans, and endangered species recovery. Amendments to Chapter 195D are needed to ensure that the most up-to-date data and research are adequately assessing the environmental issues at hand. The last attempted revision to the Endangered Species act of 1973 was in 2005, in which then-Rep. Richard W. Pombo (R) proposed that the provisions of the Act cease to have any force and effect on October 1, 2015. Though this was never introduced to the house of representatives for voting or deliberation, the need to intertwine the IUCN and the Endangered Species Act of 1973 is necessary. The IUCN is a democratic environmental network and the only international observer in the UN General Assembly with expertise in the environment, with an emphasis on biodiversity, nature, and conservation ("United Nations General Assembly" 2020). Apart from our need as a nation to align ourselves with the Paris Agreement, it is crucial to ensure that the viability of endangered and threatened species have annually updated classifications to better assess and rectify the most prominent obstacles faced by those particular populations.

With the implementation of any sort of conservation actions, it is important, to begin with assessing the extent of the external costs to society widespread marine biodiversity loss would cause. Throughout this thesis, we've noted the importance of the Hawaiian Green Turtle

(*Chelonia mydas*) and its ability to provide key habitats for surrounding marine biota through the maintenance of seagrass beds and coral reef ecosystems, which in turn balances marine food webs, and facilitates marine food webs. Should the Hawaiian Green Turtle (*Chelonia mydas*) face functional or mass extinction, externalities would likely have profound damages and possibly stunt the continuation of anthropogenic growth and development. As noted in Chapter 1, There has been a strong correlation between altered nest temperature and metabolic heat creating a feminizing effect during the middle third of the incubation period when sex is determined (Önder, B. F. and Candan, 2016). If all the mature individuals have no one to mate with, significantly reducing the likelihood of maintaining the increasing population trends, the Hawaiian subpopulation of *Chelonia mydas* would certainly face functional extinction. A mass extinction would follow suit considering that these particular organisms are endemic and do not exist elsewhere.

Other externalities that would have a direct impact on the furtherment of anthropogenic development include widespread food change damages as a result of biodiversity loss that could induce an issue regarding food accessibility and food scarcity. If the overall fishing catch is severely disrupted, the prices for seafood would experience drastic fluctuations in price. These changes could negatively affect public health as starvation would ensue from a loss or scarcity in one of the main food groups for the residents of the Hawaiian island chain. The Hawaiian fishing industry accounts for a large part of socioeconomic wellbeing, therefore, it is crucial to take the aforementioned concerns into account when devising conservation efforts. I would recommend that the City and County of Honolulu's Department of Environmental Services thoroughly assess the ecological health of the Hawaiian Green Turtle (*Chelonia mydas*) population and measure the data against each individual U.S. dollar spent on Hawaiian ecotourism, fishing revenues from both commercial and longline fisheries, in addition to the current plastic bag consumption within Honolulu County. This same assessment should be done on each of the main Hawaiian Islands to allow researchers to develop a more comparative understanding of the current state of the ever-present human-wildlife conflict and the economic worth of investing state funds into preserving a flagship species like the Green Turtle (*Chelonia mydas*).

Marine Protected Areas, or "MPAs" have been implemented throughout the main Hawaiian island chain since 1999 to protect marine biodiversity and prevent vulnerable ecosystems from enduring environmental stressors as a result of habitat loss (Stevenson *et al.* 2013). Initially, the MPA network was made up of nine Fish Replenishment Areas (FRAs) that prohibited the illegal removal of any species for illegal aquarium trades (Stevenson *et al.* 2013). Though 35.2% of the Fish Replenishment Areas have since closed, the illegal aquarium trade was able to remain lucrative and continued to export the largest quantity of reef fish in the entirety of Hawaii state (Stevenson *et al.*, 2013). The yellow tang (*Zebrasoma flavescens*) was increasingly harvested by approximately 33% since the implementation of the Marine Protected Areas, hence the reason their population trends have declined by an estimated 45% over an 8-year duration from 1999 through 2007 (Stevenson *et al.*, 2013). The case of the yellow tang (*Zebrasoma flavescens*) is unfortunate considering these Marine Protected Areas are meant to enhance the fishing industry as the stock populations are given the ability to recalibrate and regain stasis within their respective protected zones (Stevenson *et al.*, 2013). However, the true efficiency of the MPA remains controversial as the ecological, social, and economic benefits have yet to be clearly understood (Stevenson *et al.*, 2013). While Marine Protected Areas are assessed and determined by scientists who value the intrinsic and moral rights of the fish inhabiting the ecosystem over the success of longline and commercial fisheries, I believe regulating zoning laws would help offset the noted less than ideal fishing behavior (Stevenson *et al.*, 2013). Marine Protected Areas have been known to reduce overall fishing profits and have led fishers to either fish in less desirable areas or simply fish near the MPA boundary lines (Stevenson *et al.*, 2013).

Competition among fisheries is heightened when crowding occurs as a byproduct of displacement (Stevenson *et al.*, 2013). Should the commercial–both large and small scale–and longline fisheries no longer be able to provide extensive employment opportunities due to loss of fishing grounds, this would not only have social costs but incentivize fishers to seek better opportunities in non-Marine Protected Area bounds (Stevenson *et al.*, 2013).

Marine Protected Areas provide protection for the Main Hawaiian Islands, providing protection over Oahu and the Hawaiian Green Turtles (*Chelonia mydas*) basking and nesting grounds throughout Laniakea Beach on the North Shore. Having discussed the pros and cons attributed toward the implementation of Marine Protected Areas, the overall outcome has led to an overall minimalization of disturbances to threatened marine biota. The Northwestern Hawaiian Islands benefit from UTM Zone 3N ("Northwest Hawaiian Islands: UTM Zone 3N | Pacific Islands Benthic Habitat Mapping Center", n.d.). The study areas within the UTM Zone 3N include the Gardner Pinnacles, Brooks Banks, French Frigate Shoals, Necker Island, and Twin Banks ("Northwest Hawaiian Islands: UTM Zone 3N | Pacific Islands Benthic Habitat Mapping Center", n.d.). The Gardner Pinnacles is the smallest landmass in the Northwestern Hawaiian Islands and lies in between the French Frigate Shoals and the Maro Reef ("Northwest Hawaiian Islands: UTM Zone 3N | Pacific Islands Benthic Habitat Mapping Center", n.d.). Being that all the Hawaiian Islands lie in a northwestern orientation due to the constant movement of the Pacific plate, they eventually submerge under sea level ("Northwest Hawaiian Islands: UTM

Zone 3N | Pacific Islands Benthic Habitat Mapping Center", n.d.). The Gardner Pinnacles is both the largest and most northwestern basalt rock in the archipelago ("Northwest Hawaiian Islands: UTM Zone 3N | Pacific Islands Benthic Habitat Mapping Center", n.d.). The French Frigate Shoals is an open atoll with a total landmass of 0.23 square kilometers with surrounding reefs covering 733 square kilometers with depths no greater than 100 meters ("Northwest Hawaiian Islands: UTM Zone 3N | Pacific Islands Benthic Habitat Mapping Center", n.d.). Of the French Frigate Shoals, Tern Island and the Hawaiian Green Turtle (*Chelonia mydas*) rookeries enjoy the benefits of the Papahānaumokuākea Marine National Monument expansion. One proposed amendment to the UTM Zone 3N would be to allocate specific protections for the Hawaiian Green Turtle (*Chelonia mydas*) given their seasonal breeding residency at the French Frigate Shoals. The ecotourism that occurs at Tern Island should direct efforts to protect both terrestrial and marine habitats that reside within the UNESCO boundraies. With the passing of comprehensive environmental legislation, it would be quite feasible to establish strengthened protection and restoration of Hawaiian Green Turtle (*Chelonia mydas*) populations and increase zoning around rookeries present within the Northwestern Hawaiian Islands.

The State of Hawai'i Division of Aquatic Resources has introduced the Holomua: 30x30 Marine Initiative. The initiative was first proposed at the International Union for Conservation of Nature World Conservation Congress in Hawaii by Governor David Ige. Governor Ige announced the Sustainable Hawaii Initiative which included the Holomua: Marine 30x30. The Holomua: Marine 30x30 aims to dedicate at least 30% of nearshore waters as marine management areas with its core focus on monitoring methodologies, place-based planning, protection and restoration, and pono practices ("30×30 Initiative", 2016). Monitoring is meant to follow, track, and reinforce the management approaches and identify areas that need to be amended to better manage threatened species ("30×30 Initiative", 2016). The Place-Based Planning allows the fisheries and community to work alongside the state to enact cohesive and effective policies that account for marine health and economic vitality ("30×30 Initiative", 2016). The Protection and Restoration aspects work toward preventing further degradation to nearshore ecosystems and rehabilitate the areas that are most in need of intervention ("30×30 Initiative", 2016). The pono practices emphasize the importance of conservation and invite citizen scientists to engage in environmental policy reform. Through education and outreach programs, local residents are encouraged to strengthen local enforcement near the nearshore protected regions, update and advocate for regulations, and enhance local partnerships among the community and state government ("30×30 Initiative", 2016).

The Holomua: 30x30 Marine plan is set to be fully enacted in 2030, however, I believe this multi-step initiative should anticipate full enactment by 2025. Within the marine management areas, the zoning laws are set to be monitored strictly during the summer when the Hawaiian Green Turtle (*Chelonia mydas*) are breeding ("30×30 Initiative", 2016). In a similar manner, zoning was instilled by the Australian government in 1980 to improve fish stocks but began to greatly expand in 2004 due to the stark benefits displayed in reef health. The blue zones permitted fishing while green zones are heavily protected. Due to the aforementioned overfishing, the blue zones had a disproportionate number of prey and not enough predators to regain stability. On the contrary, green zones were pristine and had up to five times the number of predators displayed within the blue zones. The Great Barrier Reef's rezoning efforts in 2004 allowed the overall marine turtle abundance at all levels to increase significantly whilst gaining increased protection from fisheries. With the Sustainable Hawaii Initiative, we can predict that designating management areas will facilitate increased survivorship of the Hawaiian Green

Turtle (*Chelonia mydas*). While the Great Barrier Reef sought to protect the Hawksbill Turtle (*Eretmochelys imbricata*), we can make comparisons to the current Hawaiian Green Turtle (*Chelonia mydas*) increasing population trend–the IUCN has noted that the current number of mature individuals is 6,500–and infer that there is a substantial need for increased zoning laws. While the new zoning laws would have an impact on the areas designated to recreational, commercial, and longline fisheries, they will simultaneously increase the density of fish available in the local marine environment. Revised zoning would effectively negate the initial impact just after 2025. By predicting a reduction in fishable areas around the Hawaiian Island Chain, the catch would experience an overall reduction within the first five years of implementation but result in an increased fish density with a faster rebound rate than the projections set forth for the proposed Holomua: 30x30 deadline ("30×30 Initiative", 2016).

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