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Nichola A. Clark
Trinity College, nichola.clark@trincoll.edu

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Invasion of Reservation:
U.S. policy responses to the invasive lionfish within Marine Protected Areas

PBPL Senior Thesis

Nichola A. Clark
Class of 2012

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The Public Policy and Law department at Trinity College truly is outstanding. Professor Fulco in particular deserves attention for developing a program that has, in a very short amount of time, become one of the most popular majors at this school. This newfound popularity is no mere coincidence; the courses in the Public Policy department are interesting, practical, and engaging. Between practicing for group presentations for Professor Fulco's class and late nights at the library preparing for oral arguments in Professor Cabot's class, Public Policy majors form a tight-knit community that absolutely improves both the intellectual and social experience at Trinity. I am particularly grateful to Professor Fulco for her guidance and flexibility as my major advisor, for the absurd number of letters of recommendation that she provided for my scholarship and graduate school applications, and for her genuine interest in and care for my current and future endeavors.

More generally, I would like to thank my parents for their love and unwavering support and my sister for keeping me simultaneously entertained and humbled. Thank you to my friends, Jess Cote and Julia Melnick in particular, who have helped me through times I would rather forget and replaced them with my fondest memories. Finally, I am thankful to Allison Read for helping me discern my priorities and find balance in life.

Introduction

When I arrived in the Turks and Caicos Islands for a study abroad program on Marine Protected Areas (MPAs), I thought that it was my farewell to science; I planned to pursue a degree in non-profit policy when I returned to Trinity. Instead, I found a new passion and a new academic interest: marine policy. Two years after my initial encounter with marine studies, I was offered an internship at the Cape Eleuthera Institute (CEI) in Eleuthera, Bahamas. CEI hired me to work as a research assistant for a graduate student who was studying lionfish (looking specifically at their movement patterns in relation to their reproductive behaviors). I was vaguely familiar with the invasive lionfish from my time in the Turks and Caicos—lionfish hunting was a very popular Saturday afternoon activity. When I got to the Cape Eleuthera Institute, I learned that my job as a research assistant specifically included catching lionfish and then holding the poisonous fish down underwater while the researcher took blood samples and tagged the specimen. However, when the CEI administration learned that I had an interest in and some experience with MPAs, they assigned me the additional task of authoring a white paper calling for the establishment of a marine reserve on the island. So, my time in Eleuthera was split—lionfish wrangler by day, marine reserve advocate by night.

When I returned to the U.S. and started to think about my thesis topic for public policy, I wanted a way to try to incorporate my two marine research interests. What role did lionfish play in marine protected areas? I started thinking back on my time in

the Turks and Caicos, where we studied the benefits of MPAs by comparing South Caicos' MPA to non-protected areas. Then it hit me—I did not personally take part in lionfish hunting there, so I wondered if it occurred within the boundaries of a MPA. Did they make an exception to the "take only pictures, leave only bubbles" rule of the marine reserve in order to remove this invasive species? How did U.S. policy react to the lionfish invasion? Specifically, did marine reserves make an exception to their "no-take" rules in an attempt to control the lionfish population?

This thesis is the result of the exploration of the issues mentioned above. After giving a background on both Marine Protected Areas and the Indo-Pacific lionfish invasion of the western Atlantic and Caribbean, I describe different ways in which marine policies have changed in response to the invasion. After evaluating the effectiveness of these different responses, I conclude with an ethical discussion of the *appropriateness* of lionfish control strategies (an idea inspired by my study of "killability" at Oxford); after all, it is more than a little ironic that we humans are trying to eradicate an entire species with the justification that *they* are destroying the environment.

Chapter One: Background on Marine Protected Areas

Newfoundland Canada used to have oceans full of so many cod that it was rumored "that a man could walk across the waters on their backs"[1]. Indeed, in the 1950s, Newfoundland cod were so plentiful that they instigated a 'cod rush' that attracted over twenty fishing nations[2]. The entire community built up around the fishing industry. As technology improved, fishermen were able to catch even more fish and enjoyed correspondingly greater prosperity. And then, suddenly in 1992, there were no more fish. According to Doug Sweetland, a local fisherman at the time of the collapse, "In the winter of '92 there was good cod. Within three months there was nothing."[3] The government put a ban on fishing cod, but it was too late—the cod had been fished to the point of extinction. 40,000 men were out of a job, and the fishing community lost its soul. To this day, although the fishing moratorium has been in effect since 1992, the fish still have the status of "endangered species" in the Newfoundland seas; cod were fished to such an extent that the population has no hope of ever recovering[4].

The Newfoundland fisheries are a chilling example of what could happen to the world's oceans on a global scale if current fishing practices continue. And indeed,

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[1] *The End of the Line*, DVD, directed by Rupert Murray (2009; Docuramafilms).

[2] Dean Bavington, *Managed Annihilation: An Unnatural History of the Newfoundland Cod Collapse* (Canada: UBC Press, 2010).

[3] Charles Clover, *The End of the Line: How Overfishing is Changing the World and What We Eat* (New York: The New Press, 2006).

[4] *The End of the Line*.

global statistics are distressing. Global fish stocks are declining at a rapid rate and scientists estimate that we have depleted 90 percent of the world's large-fish stock[5]. The United Nations Food and Agriculture Organization (FAO) estimates that since 1990, one in four fish stocks have been over-exploited, depleted, or is recovering from depletion.[6] The FAO also estimates that by 2030, there will be a 40 million ton global seafood shortage.[7] The National Oceanic and Atmospheric Administration (NOAA) predicts that by 2025, the United States alone will have a seafood shortage of two million tons. If current fishing practices and consumption demands continue, scientists predict that the stocks of all currently consumed fish will collapse by 2048[8]. In the United States, commercial and recreational fishing amount to $162.9 billion in sales; the United States imports over 85 percent of its seafood and has a seafood trade deficit of over $10 billion[9]. Declining fish stocks create an ecologically and economically grim state of affairs but recently, scientists and governments have turned to marine reserves, or marine protected areas (MPAs), as a potential solution to this problem.

A MPA is most commonly defined as "An area of land and/or sea especially dedicated to the protection of biological diversity, and of natural and associated cultural

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[5] R. Myers and B. Worm, "Rapid Worldwide Depletion of Predatory Fish Communities," *Nature*, 423 (2003): 280-283.

[6] J. R. Beddington, D.J. Agnew, and C.W. Clark, "Current Problems in the Management of Marine Fisheries," *Science,* 316, no. 5832 (2007): 1713-1716.

[7] NOAA, "Seafood Consumption Increases in 2006," NOAA, 2007. http://www.publicaffairs.noaa.gov/releases2007/jul07/noaa07-r123.html.

[8] Boris Worm, Edward B Barbier, Nicola Beaumont, et al., "Impacts of biodiversity loss on ocean ecosystem services," *Science* 314, no. 5800 (2006): 787-90.

[9] Joe Myers, "U.S. Seafood Trade Surpasses $10 Billion for the First Time," *National Association of State Aquiculture Coordinators*, 2011.

resources, and managed through legal or other effective means"[10]. In practice, this often translates to an area of ocean (and potentially the surrounding land) being closed off to fishing in an attempt to rebuild the marine ecosystem or to preserve a historically important site. This generalization is indeed an oversimplification; there are in fact several types of MPAs and they can be classified according to several different criteria: conservation focus (natural heritage, cultural heritage, and/or sustainable production); level of protection afforded (uniform multiple-use, zoned multiple-use, zoned with no-take area, no take, no impact, or no access); permanence of protection (permanent or temporary; constancy of protection (year-round, seasonal, or rotating), and the ecological scale of protection (ecosystem or focal resource)[11]. Indeed, marine protected areas may have many roles. A MPA used to preserve biodiversity and genetic diversity, to conserve ecosystems and maintain ecological processes, to protect commercially valuable species, to replenish depleted stocks, for education and research, for protection from natural hazards, or for recreation and tourism[12]. This thesis will largely focus on MPAs used to preserve biodiversity/genetic diversity, conserve ecosystems, protect commercially valuable species, and/or replenish depleted stocks. It is also important to note that all marine reserves are MPAs, but not all MPAs are marine reserves. A marine reserve is most often specifically a 'no-take' area (which, as the name might imply, means that *nothing* within the reserve can be removed or destroyed);

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[10] IUCN, *Guidelines for Protected Area Management Categories* (Gland, Switzerland and Cambridge, UK: IUCN, 2000).

[11] NOAA, "About Marine Protected Areas," *National Marine Protected Areas Center*, http://www.mpa.gov/aboutmpas/.

[12] IUCN, *Guidelines*.

in fact, only three percent of U.S. waters are no-take areas[13]. However, because the term 'reserve' will be used frequently throughout this thesis to refer to a protected area in general, any reserves that are no-take areas will be specifically clarified as such.

Marine Protected Areas are administered in a variety of ways. In the Bahamas, for example, a government designated NGO/non-profit (The Bahamas National Trust) is responsible for managing the country's system of marine reserves[14]. However, because this thesis largely focuses on the United States, I will specifically look at MPA administrative practices in the United States. MPAs can be established at every level of government and within each level can be administered by a variety of agencies. At the federal level, MPAs are managed by both the Department of Commerce in conjunction with the National Oceanic and Atmospheric Administration (NOAA) and by the Department of the Interior. State designated MPAs are managed by over one hundred different agencies. There are also some MPAs managed by tribal or local agencies.[15] On May 26, 2000 President Clinton called for a national system of Marine Protected Areas (Executive Order 13158)[16]. NOAA's National Ocean Service (NOS) together with the Department of Interior are largely responsible for carrying out President Clinton's executive order. The most critical aspect of this implementation was the creation of the National MPA Center, which is responsible for fulfilling the different mandates of the

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[13] NOAA, "Snapshot of United States MPAs,"Office of Ocean and Coastal Resource Management, NOAA Ocean Service, April 2011, http://www.mpa.gov/pdf/helpful-resources/us_mpas_snapshot.pdf.

[14] The Bahamas National Trust, "About Us", http://www.bnt.bs/_m1713/About-Us.

[15] NOAA, "Definition," *About Marine Protected Areas*, NOAA, http://www.mpa.gov/aboutmpas/definition/.

[16] William J. Clinton, "Executive Order 13158 of May 26, 2000," *The Federal Register,* 65 no. 105 (2000):34909-34911.

executive order. The mission of the National MPA Center is to

> facilitate the effective use of science, technology, training, and information in the planning, management, and evaluation of the nation's system of marine protected areas.
>
> The National MPA Center works in partnership with federal, state, tribal, and local governments, tribes, and stakeholders to develop and implement a science-based, comprehensive national system of MPAs. These collaborative efforts are intended to ensure more efficient, effective use of MPAs now and in the future to conserve and sustain the nation's vital marine resources.[17]

The National MPA Center has three main goals: "To build and maintain a national system of Marine Protected Areas", "to "improve MPA stewardship and effectiveness", and to "facilitate international, national, and regional coordination of MPA activities"[18].

The United States actually has a relatively impressive number of MPAs. As of April 2011, the U.S. has over 1600 MPAs which cover approximately forty percent of its waters. To put that number in perspective, approximately 1.42 percent of the world's oceans are protected[19]. As previously mentioned, approximately three percent of U.S. waters are no-take areas. In terms of numbers of MPAs, only six percent are entirely

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[17] NOAA, "National MPA Center," NOAA. http://www.mpa.gov/aboutmpas/mpacenter/
[18] Ibid.
[19] Nicola Jones, "Marine Protection Goes for Larger Swaths of Sea," *Nature* (2011): 292.

no-take areas and an additional two percent are zoned with no-take areas[20]. However, The Federal Government manages approximately 22 percent of all MPA sites and State governments manage approximately 72 percent of MPA sites. However, because Federal sites tend to be significantly larger than state (or other) sites, the Federal Government actually manages 98 percent of protected areas (by area)[21]. (See Appendix A).

MPAs have proven to be effective management tools and when appropriately administered, can yield significant increases in stock populations. A report that examined 89 studies of reserves concluded that in an analysis of all species, 63 percent of the reserves had a higher density, 90 percent had a higher biomass, 80 percent had larger organisms, and 59 percent had higher diversity.[22] So, there are more types of species, more organisms of those species, and those organisms are larger. A more recent study of 124 different no-take marine reserves found an average of 466 percent increase of biomass within a marine reserve, 166 percent increase in density, an animal body size increase of 28 percent, and a species density increase of 21 percent[23]. A specific example of the potential of MPAs, and of its dependence on proper enforcement, can be found in the study of Sumilon Island. In 1974 25 percent of the reef of Sumilon Island was closed to fishing; nine years later, fish were twice as abundant

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[20] NOAA, "Snapshot of United States MPAs".

[21] Ibid.

[22] B. S. Halpern, "The impact of marine reserves: Do reserves work and does reserve size matter?" *Ecological Applications* 13 (2003) :S117-S137.

[23] S. Lester et. al., "Biological Effects Within No-Take Marine Reserves: a Global Synthesis," *Marine Ecology Progress Series* 384 (2009): 33-46.

inside the reserve compared to outside of the reserve and grouper inside the reserve specifically had over six times the biomass and twice the mean weight of grouper outside of the reserve. However, in 1984 the Sumilon Island government changed and the marine reserve was no longer enforced. After only one year of unchecked fishing, the fish density within the reserve fell by 25 percent; specifically, grouper density fell by 49 percent and snapper density by 94 percent. There was no change in fish density outside of the reserve.[24] Another example of MPA success can be found in the Bahamas Exuma Cays Land and Sea Park (ECLSP). Evidence suggests that not only are there more and larger fish within the MPA, but that there are also "more fish outside of the MPA available to fishers"[25]. Conch density is 31 times greater inside the ECLSP reserve compared to outside the reserve; approximately three-fourths of the grouper in the Northern Exuma region come from the reserve and grouper tagged in the reserve have been fished as far as 150 miles outside the park[26]. The benefits of MPAs are very obvious within the MPA, but how exactly does this benefit improve the ecosystems and target populations outside of the MPA?

The two processes by which MPAs compensate for the area lost to fishing are called the spillover effect and larval transport. The spillover effect describes "the enhancement of local fisheries by emigration of adults and large juveniles from a

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[24] G. R. Russ and Alcala A.C., "Sumilon Island Reserve: 20 Years of Hopes and Frustrations," *Naga, The ICLARM Quarterly* (1994): 8-12.

[25] R. Stoffle and J. Minnis J, "Marine protected areas and the coral reefs of traditional settlements in the Exumas, Bhamas," *Coral Reefs* 26 (2007):1023-1032

[26] The Bahamas National Trust, "The Success of the Exuma Cays Land and Sea Park as a Marine Fishery Reserve," *The Exuma Cays Land and Sea Park*, BNT, 2009. http://www.bnt.bs/marine_reserve_success.php.

reserve"[27]. In other words, many of the increased fish population within the reserve will migrate *outside* the reserve where they can legally be fished. While there is less empirical evidence to support the spillover effect compared to that of MPAs success, several studies have still found support for its existence. Alcala and Russ (1990) found that after the breakdown of a marine reserve, the catch-per-unit-effort (CPUE) declined by 57 percent for hook and line, 58 percent for gill net and 33 percent for trap fishing[28]; this significant decline in catch is even more staggering when one takes into account that the overall area of fishing had increased to include the area that was formerly the reserve. Other studies record lobster tagged within a reserve being caught outside of the reserve by fishermen[29]. Though the spillover effect is more difficult to measure than the increase in fish density, size, etc. within a MPA, many studies have still managed to gather proof to support this theory.

Perhaps even more difficult to prove (though potentially more powerful) than the spillover effect is the theory of larval transport, or "the enhancement of regional fisheries by export of larvae from a reserve"[30]. This idea is difficult to prove only because it is practically impossible to tag and track larval migration; however, models and simulations allow scientists to estimate the effects of larval transport. Though the significance of larval transport depends more considerably on species, size of the

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[27] R. J. Rowley, "Case studies and reviews: Marine reserves in fisheries management," *Aquatic Conservation: Marine and Freshwater Ecosystems* 4 (1994): 233-254.

[28] A. C. Alcala and G. R. Russ, "A direct test of the effects of protective management on abundance and yield of tropical marine resources," *Journal du Counseil International pour I'Exploration de la Mer* 46 (1990): 40-47.

[29] A. B. MacDiarmid and P. A. Breen, "Spiny lobster population changes in a marine reserve," *Proceedings of the Second International Temperate Reef Symposium* (1992): 47-56.

[30] Rowley, "Case Studies and Reviews".

reserve, fishing pressures, and flow patterns, numerical modeling simulation indicates that reefs are effective sources of larval dispersal[31][32][33]. An additional benefit of MPAs in regards to larval transport is that larger-sized females (which have a higher abundance in MPAs) produce significantly more eggs. For example, it would take 212 large female Atlantic red snapper (*Lutjanus campechanus*) in an *unprotected* fishery (who might reach 42 cm in length) to produce the same number of eggs as one large female in a protected reserve fishery (who could reach 61 cm in length and produce as many as 9 300 000 eggs)[34]. Conservative studies from the ECLSP estimate that, largely through this process of larval transportation, the marine reserve provides "several million conch outside the park for fishermen [in the Bahamas] to harvest each year"[35]. The benefits of MPAs extend beyond their reserve borders—through spillover and larval transport, areas outside of protected areas witness healthier, or at least more abundant, marine life.

Although the topic will not be covered in this thesis, it is important to stress that community involvement and support is integral to the success of an MPA. Unless the community decides to work together to follow and enforce the guidelines of the MPA,

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[31] I. J. Dight, L. Bode, and M. K. James, "Modelling the larval dispersal of *Acanthasterplanci* I. Large scale hydrodynamics, Cairns Section, Great Barrier Reef Marine Park," *Coral Reefs* 9 (1990a): 115-123.

[32] I. J. Dight, M.K. James, and L. Bode, "Modelling the larval dispersal of *Acanthasterplanci* 11. Patterns of reef connectivity," *Coral Reefs* 9 (1990b): 125-134.

[33] M. K. James, I. J. Dight, and J. C. Day, "Application of larval dispersal models to zoning of the Great Barrier Reef Marine Park," in *Proceedings of the Pacific Congress on Marine Science and Technology, Tokyo, Japan, 16-20 July 1990*.

[34] Plan Development Team, "The Potential of Marine Fishery Reserves for Reef Fish Management in the U.S. Southern Atlantic," *NOAA Technical Memorandum*, U.S. Department of Commerce, Washington, 1990.

[35] The Bahamas National Trust. "The Success of the Cays".

the reserve cannot hope to fulfill its purpose. Therefore, in addition to properly enforcing the laws of MPAs, it is imperative that administrators work together with the community to establish clear and sustainable MPA regulations.

Chapter Two: Lionfish and their Invasion of the Atlantic

"Lionfish are the first non-native marine fishes to establish in the Western North Atlantic and Caribbean Sea"[36]. Lionfish only recently invaded American and Caribbean coasts and consequently, their full impact is yet to be determined. However, their alarmingly rapid spread throughout the eastern Atlantic and Caribbean waters, in addition to their success in their newfound environments signify that lionfish could have deleterious effects on Atlantic reef ecosystems.

Lionfish are native to the Indo-Pacific. The first lionfish sighting in the United States was in October of 1985 off of the coast of Florida[37]. The species was not seen again until 1992 when, as a result of Hurricane Andrew, six lionfish escaped from a seaside Florida aquarium.[38] These six lionfish were reportedly spotted, alive, a few days after. The next recorded lionfish sightings were not until 2000 when four were seen off the coast of Florida, one was seen off of South Carolina, and three were reported on the North Carolina coast. The next year, five specimen were seen in Florida, three in Georgia, ten in South Carolina, fourteen in North Carolina, and even two in New York. "By 2002, lionfish were considered more or less continuously

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[36] P. J Schofield, "Geographic extent and chronology of the invasion of non-native lionfish (Pterois volitans [Linnaeus 1758] and P. miles [Bennett 1828]) in the Western North Atlantic and Caribbean Sea," *Aquatic Invasions* 4, no. 3 (2009), 473–479.

[37] J. A. Morris Jr. and J. L. Akins, "Feeding ecology of invasive lionfish (Pterois volitans) in the Bahamian archipelago," *Environ Biol Fish* 86 (2009): 389-398.

[38] W. R. Courtenay Jr., "Marine fish introductions in southeastern Florida," *American Fisheries Society Introduced Fish Section Newsletter* 14 (1995): 2-3.

distributed from Miami, Florida to Cape Hatteras, North Carolina."[39] Within the Caribbean, the Bahamas has had a particularly prolific population of invasive lionfish; the first lionfish was in the Bahamas was not sighted until 2004.[40] (See Appendix B for a diagram of the increase and spread of lionfish in the Western Atlantic and Caribbean.) In addition to being the first invasion of a marine fish to the West Atlantic/Caribbean, the lionfish invasion represents "one of the most rapid marine finfish invasions in history"[41].

Lionfish are very popular in the aquarium trade and most scientists agree that the lionfish invasion is a direct result of lionfish being intentionally or unintentionally released from Florida aquaria. Invasive lionfish populations have significantly less genetic diversity than native populations. This lack of genetic diversity confirms a strong founder effect (the founder effect describes the phenomenon of a few individuals becoming isolated from a larger population and establishing a new population whose gene pool differs from the source population[42]). While it has been rumored that the six lionfish released from the aquarium during Hurricane Andrew is the sole source of the lionfish invasion (in and of itself unlikely since the first lionfish sighting in Florida occurred in 1985, seven years before the hurricane), studies show that there had to be between eight and twelve individual specimen to account for the genetic diversity

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[39] Schofield, "Geographic extent and chronology".

[40] Ibid.

[41] J. A. Morris Jr., et al., "Biology and Ecology of the Invasive Lionfishes, *Pterois miles* and *Pterois volitans*," *GCFI* 61 (2009): 409-414.

[42] Neil A. Campbell and Jane B. Reece. *Biology*. Benjamin-Cummings Pub Co, 2008. 476.

found in the entirety of the invasive lionfish population[43]. Although the six lionfish released from the aquarium cannot be held completely responsible for the lionfish invasion, it is entirely possible that they made up one-half to three-quarters of the founding individuals.

In order to understand exactly *how* lionfish have been so successful in taking over Western Atlantic reef ecosystems, one need look no further than their physical appearance (See Appendix C). The lionfish is covered with brown or maroon and white strips or bands. They have thirteen dorsal spines, ten to eleven dorsal soft rays, three anal spines, six to seven anal soft rays, fan-like pectoral fins, and tentacles under their mouth and above their eyes.[44] The lionfish's spines is covered in an integumentary sheath contain venom which is a combination of a protein, a neuromuscular toxin, and a neurotransmitter called acetylcholine[45]. "Lionfish envenomation occurs when the spine's integumentary sheath is depressed as it enters the victim. This process tears the glandular tissue allowing the venom to diffuse into the puncture wound."[46] Lionfish venom can have a variety of cardiovascular, neuromuscular, and cytolytic effects. The severity of reaction ranges from swelling and other mild reactions to "extreme pain and paralysis in upper and lower extremities"[47]. Lionfish are not aggressive towards

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[43] R. Betancur-R., R., et al. "Reconstructing the lionfish invasion: insights into Greater Caribbean biogeography," *Journal of Biogeography 38*, no. 7 (2011): 1281-1293.

[44] National Ocean Service, "Lionfish Biology Fact Sheet," *NOAA,* http://oceanservice.noaa.gov/education/stories/lionfish/factsheet.html. 31 May 2011.

[45] Ibid.

[46] Morris et al., "Biology and Ecology of the Invasive Lionfishes, *Pterois miles* and *Pterois volitans*".

[47] K.W. Kizer, H.E. McKinney, and P.S. Auerbach, "Scorpaenidae envenomations: A five-year poison center experience," *Journal of the American Medical Association* 253 (1985):807-810.

humans but divers must still use extreme caution when diving in areas occupied by lionfish.

Lionfish prefer warm waters and can be found at depths ranging from one to one thousand feet. Although some lionfish are found north of North Carolina, it is thought that the species will be unable to permanently occupy these waters because its water temperature is too cold. Lionfish are generally slow-moving animals and tend to retreat to caves, ledges, and crevices in reef environments during the day[48]. It is important to note that all population estimates of lionfish should be considered to be conservative because of lionfish's tendency to hide in caves (making an accurate count nearly impossible). Further research needs to be done in order to determine the hunting patterns of lionfish (it is believed that they are nocturnal hunters, but very few studies have followed these animals' behavior at night and additionally, lionfish have been found to have full stomachs in the middle of the day). Lionfish use their elaborate and intimidating pectoral fins to herd and corner their prey and then attack them with a rapid strike[49]. A 2010 study found that lionfish consume large numbers of large prey. A lionfish is capable of consuming prey up to half of its own size[50]. In one single observation within that study, researchers observed a single adult lionfish consume twenty small wrasses within a thirty-minute period[51]. Lionfish consume between 2.5

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[48] National Ocean Service, "Lionfish Biology Fact Sheet".

[49] M. Albins and M. Hixon, "Invasive Indo-Pacific lionfish *Pterois volitans* reduce recruitment of Atlantic coral-reef fishes," *Marine Ecology Progress Series* 367 (2008): 233-238.

[50] Morris and Akins, "Feeding ecology of invasive lionfish *Pterois volitans* in the Bahamian archipelago".

[51] Morris et al. "Biology and Ecology of the Invasive Lionfishes, *Pterois miles* and *Pterois volitans*".

and 6 percent of their body weight every day. However, even if a lionfish were unable to find any food, it would still be able to survive for twelve weeks[52].

Its physical build and behavior make the lionfish a particularly effective predator. A recent study found that lionfish are capable of removing approximately 79 percent of the prey community on an isolated patch reef[53]. The first assessment of lionfish density was conducted in 2007 off of the coast of North Carolina. This study

> …reported an average of 21 lionfish per hectare across 17 locations in 2004. Lionfish densities off North Carolina have continued to increase. Recent assessments off New Providence, Bahamas indicate lionfish densities are more than 18 times higher than the 2004 North Carolina estimates.[54]

It is interesting to note that lionfish population density estimates in the Bahamas are approximately *eight* times the density of lionfish in their native range.

Why are lionfish so successful in their newfound Atlantic and Caribbean habitats? In addition to their phenomenal predatory tools, lionfish also have high levels of reproduction. Rather than having a particular season during which they mate, lionfish mate every four days, year-round and produce over two million eggs every year[55]. Additionally, lionfish have no known natural predators. While sharks and

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[52] Ibid.

[53] Albins and Hixon. "Invasive Indo-Pacific lionfish *Pterois volitans* reduce recruitment of Atlantic coral-reef fishes."

[54] Morris et al., "Biology and Ecology of the Invasive Lionfishes, *Pterois miles* and *Pterois volitans.*"

[55] Betancur-R. et al."Reconstructing the lionfish invasion: insights into Greater Caribbean biogeography."

grouper have been known to occasionally eat lionfish, a laboratory behavioral study found that even if starved, grouper actively avoided lionfish[56].

Overfishing of shark and grouper in the Atlantic and Caribbean has also contributed to the rapidly increasing lionfish population. In addition to being a *potential* predator to the lionfish, the grouper occupies the same ecological niche as the lionfish. In other words, because there are significantly fewer numbers of grouper in Atlantic and Caribbean environments (due to overfishing), there population size of the prey grouper consume increased. The greater number of fish that are lower on the food chain is able to sustain a larger population of lionfish. Additionally, lionfish are able to outcompete the grouper population that does exist because the prey for which the two species compete is not familiar with the lionfish or its hunting behavior and therefore is ill-adapted to respond to lionfish predation. This naivety of Atlantic prey also explains why invasive lionfish are more successful than native lionfish (whose prey have had time to adapt to lionfish hunting behavior).[57]

Although lionfish have only been legitimately established in the Atlantic for a decade, Albins and Hixon have been able to prove "that the invasive Indo-Pacific lionfish has a direct negative effect on Atlantic coral-reef fish populations."[58] In addition to being harmful to divers, lionfish consume native species and outcompete other native and economically important species. The lionfish population has grown to

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[56] Morris et al., "Biology and Ecology of the Invasive Lionfishes, *Pterois miles* and *Pterois volitans*"

[57] Albins and Hixon., "Invasive Indo-Pacific lionfish *Pterois volitans* reduce recruitment of Atlantic coral-reef fishes."

[58] Ibid.

such an extent that it is impossible to eradicate them[59]. The lionfish invasion is not the only stress on the Atlantic Ocean; climate change, overfishing, and pollution are all equally pressing threats. Indeed, the lionfish invasion in combination with these other stressors could have a catastrophically synergistic effect.

While the lionfish invasion is generally a grim situation, it can benefit the scientific world in two respects. At the moment, very little is known about the genetic changes that occur over the course of an invasion[60]. The lionfish invasion gives scientists the opportunity to gain a better understanding of how these genetic changes occur and in doing so, researchers might uncover a key to slowing or stopping the invasive population explosion. Additionally, one study[61,62] found that lionfish venom contains "antitumor, hepatoprotective, and antimetastatic effects in mice"[63] and it is therefore likely that lionfish venom could contain positive results for cancer research.

The negative effects of the lionfish invasion overwhelmingly outweigh the potential positive benefits of the invasion and many researchers agree that the population needs to be kept in check[64] (since it is virtually impossible to completely eradicate the invasive population). Indeed, "lionfish are considered to be one of the top

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[59] Ibid.

[60] K. M. Dlugosch and I. M. Parker, "Founding events in species invasions: genetic variation, adaptive evolution, and the role of multiple introductions," *Molecular Ecology* 17 (2008): 431–449.

[61] M. Sri Balasubashini, et al., "In vivo and in vitro characterization of the biochemical and pathological changes induced by lionfish (Pterios volitans) venom in mice," *Toxicology Mechanisms and Methods* 16 (2006a): 525-531.

[62] M. Sri Balasubashini, et al., "Fish venom (*Pterois volitans*) peptide reduces tumor burden and ameliorates oxidative stress in Ehrlich's ascites carcinoma xenografted mice," *Bioorganic and Medicinal Chemistry Letters* 16 (2006b): 6219-6225.

[63] Morris et al., "Biology and Ecology of the Invasive Lionfishes, *Pterois miles* and *Pterois volitans*".

[64] Albins and Hixon; Morris and Atkins; Betancur-R. et al.

fifteen global threats to conservation biodiversity"[65]. An ideal solution to this problem would be to restore grouper and shark populations in the Atlantic so that the lionfish have, if not a predator, at least a significant competitor. However, many governments have opted for the simpler method of trying to kill as many lionfish as possible. Indeed, the Bahamas issued a lionfish kill order to fishermen in 2005. Governments and non-profit conservation organizations sponsor lionfish spearing tournaments in an attempt to eliminate large numbers of lionfish. However, the solution that promises to be the most effective (in terms of both practicality and effectiveness) is to market lionfish as an edible fish. Humans in the Indo-Pacific consume lionfish and indeed, the family of Scorpaenidae (to which the lionfish belongs) "is a delicacy in Mediterranean cuisine"[66]. A recent study found that "Lionfish contain a higher percentage of healthy n-3 fatty acids than species groups such as snapper, grouper, and bluefin tuna."[67] Additionally, lionfish have relatively low concentrations of less-desirable fatty acids[68]. Most importantly (at least, most importantly for its success as a consumption item), lionfish meat is palatable and has a mild flavor. Lionfish do stand a good chance of becoming a popularly eaten fish; in fact, there is already a lionfish cookbook in publication[69]. If consuming lionfish does manage to catch on in popular culture, there is no doubt that the invasive population will be kept well in control; after all, it is high consumer

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[65] Sutherland et al., "A horizon scan of global conservation issues for 2010," *Trends Ecol Evol* 25 (2010): 1-7.

[66] Morris Jr, J. A., et al., "Nutritional properties of the invasive lionfish: A delicious and nutritious approach for controlling the invasion," *AACL BIOFLUX 4* no. 1 (2011): 21-26.

[67] Ibid.

[68] K. L. Weaver, et al., "The content of favorable and unfavorable polyunsaturated fatty acids found in commonly eaten fish," *J Am Diet Assoc* 108 (2008): 1178-1185.

[69] T. Ferguson and L. Akins, *The Lionfish Cookbook*, REEF Environmental Education Foundation, 2010.

demand that has brought species such as grouper and bluefin tuna to near extinction (which is of course, one of the reasons why the lionfish invasion was so successful in the first place). The invasive lionfish population has spread throughout the Western Atlantic at an alarming rate and unless this population explosion is contained, Atlantic and Caribbean reef ecosystems could suffer dramatic and irreversible consequences.

Chapter Three: Tension between Reserves and Invasive Species

The goal of a marine reserve is to protect the marine species within its borders in the hopes that doing so will correspondingly improve surrounding ecosystems (and of course, humans, who will also benefit from healthier and more bountiful ecosystems). Because lionfish are capable of destroying large areas of marine ecosystems, they pose a major threat to marine reserves. However, when a lionfish settles within a marine reserve, for better or for worse, it becomes a marine species that is part of that reservation. This chapter seeks to further explore the key aspects and functions of both marine reserves and the lionfish invasion in order to delineate a more cohesive understanding of the tension between marine reservations and invasive lionfish.

I discussed the technical definition of a MPA in the first chapter and now let us more closely examine the purpose of marine reserves. Although there are several functions and purposes of marine reserves, all of these can be classified into two major categories: material and spiritual[70]. A material purpose can be defined as "ensuring the sustainability of economic resources" while a spiritual purpose can be defined as "values of species protection, biodiversity conservation, and landscapes"[71]. Protection of the material can be related to the idea of "conservation" while protection of the

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[70] IUCN, *Guidelines for Protected Area Management Categories*, p. 1.
[71] Ibid.

spiritual is better classified as "environmental protection"[72]. Of course, these two purposes are not mutually exclusive. Indeed, even if the emphasis of a reserve is protection the environment ("spiritual" values) it can produce the positive externality of preserving economically valuable resources. And of course, the converse is also true (environmental protection as a means to the ultimate goal of economic benefit). Marine protected areas aim for "practical goals"; "the habitats, ecosystems, species, and communities that [they try] to conserve have present or potential commercial uses"[73]. The ultimate goal of marine reserves is to achieve the optimal balance between present and future uses of marine resources.

However, there are several ways in which the nature of marine reserves makes them significantly more difficult to understand and maintain compared to terrestrial reserves. The first, and perhaps most obvious, challenge is that marine ecosystems and organisms transcend "biogeographic provinces and political boundaries"[74]. You can put a fence around a terrestrial reserve to keep unwanted species out and protected species in; creating an oceanic equivalent to this barrier is practically impossible. Stemming from this challenge is the issue of endemism: there are very few marine organisms that are restricted to a certain, small area of the ocean. The habitats of most marine organisms are significantly larger than even the largest marine reserve. This is particularly true for migratory species. Indeed,

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[72] J. Clark, *Coastal Seas: The Conservation Challenge,* Oxford: Blackwell Science, 2000.
[73] IUCN, *Guidelines for Protected Area Management Categories*, p. 3.
[74] Ibid. p. 4.

> Three-dimensional phenomena are more marked and important in the ocean, where organisms are less tied to the solid bottom than are land organisms to the earth. Because of the fluid nature of the seas, whole biological communities exist as floating plankton-based entities distributed horizontally and vertically through broad ocean spaces.[75]

This problem of endemism makes it very difficult to evaluate the effectiveness of marine reserves. How does one count the number of fish in a marine reserve when the number constantly fluctuates as fish swim in and out of the reserved area?

Another problem of marine reserves is that people cannot see exactly what is going on underwater (or at least, not nearly as easily as people can see activities on land). This is particularly an issue in terms of enforcement of a reserve. While poaching certainly occurs within terrestrial reserves, it is much easier to spot these criminal activities on land than it is in the ocean. Indeed, boats that carry out such illegal catching can legally anchor outside of marine reserve and then individual fishermen, particularly with the aid of SCUBA gear, can swim into the boundaries of a reserve and illegally catch fish while remaining virtually undetected.

As mentioned in the previous chapter, the growing lionfish population poses a threat to the balance of marine ecosystems in the Western Atlantic and Caribbean. Many governments have responded to this threat by incentivizing the killing of lionfish through legal action and also by hosting spear-fishing tournaments. Specific policies

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[75] Ibid.

made in response to the lionfish invasion will be discussed in detail in the next chapter. Lionfish require a significant amount of effort to capture because they do not school and they tend to hide in crevices during the day. It is this practice of hiding in complex habitats, combined with its ability to live at depths of up to one thousand feet that make lionfish virtually impossible for humans to eradicate.

In spite of the seeming impossibility of completely exterminating the entire lionfish population from the Western Atlantic, governments and environmental non-profits (such as REEF) still advocate that serious efforts should be made to try to remove as many of the species as possible. This push for lionfish removal is certainly a costly one when one considers that it takes a great deal of effort to remove only a small proportion of the population; the fact that policy-makers still advocate for lionfish eradication efforts is a testament to the severity of the repercussions (present and future) of the lionfish invasion.

However, what happens when the two worlds of reservation and eradication directly collide? What is a MPA manager to do when he/she finds lionfish inside of the marine reserve? This question poses particularly important problems for the 'no-take' and 'no-impact' marine reserves because those protected areas specify that absolutely *nothing* may be removed from or destroyed at the sites. The purpose of a site's 'no-take' or 'no-impact' status is to promote conservation and help rebuild that particular ecosystem. However, as the previous chapter established, lionfish are a major destructive force in that they, more often than not, undo marine conservation efforts. Lionfish take over habitats by preying upon over forty species of (smaller) fish and

crustaceans[76] and also by outcompeting with other native piscivores, most of which are the very species that the reserve was established to protect.

What is the MPA's appropriate response to the lionfish invasion? Should sites with "no-take" and "no-impact" levels of protection make an exception in the case of lionfish and allow for the invasive species to be removed from/killed at the site? On the one hand, since the introduction of lionfish adds another species to the ecosystem, it might seem appropriate to argue that their addition increases biodiversity (one of the features that so many marine reserves aim to protect). The counterargument, however, is that while lionfish as a species in and of themselves do, initially at least, make the ecosystem more diverse, their skills as a predator, and the decrease in other fishes' populations that results, ultimately *decreases* biodiversity.

The difficulty with the lionfish invasion is that, unlike pollution, lionfish are meant to be in the ocean. In fact, they have evolved over thousands of years to become the incredibly efficient predators they are today. The lionfish is an organism that belongs in the ocean and contributes to the biodiversity of the ocean as a whole, but it is also a force of nature that threatens the biodiversity and even survival of ecosystems in the Western Atlantic and Caribbean. If humans do ever find a way to completely eradicate lionfish from their non-native habitats, the question remains: should we? The next several chapters will explore the issues laid out here by assessing different marine

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[76] Pasko, Susan. "Lionfish". *Aquatic Nuisance Species Task Force*. http://anstaskforce.gov/spoc/lionfish.php.

policy responses and proposed responses to the lionfish invasion, evaluating their effectiveness, and then exploring the ethics of eradicating the lionfish population.

Chapter Four: Marine Policy Reactions to the U.S. Lionfish Invasion

There are many different entities that are concerned with the protection and conservation U.S. oceans and ocean resources. Consequently, marine policy reactions to the lionfish invasion come from a number of different players. This chapter will introduce the major organizations and institutions that either have responded to or inevitably will be involved with the U.S. lionfish invasion and it will also identify each entity's policy reactions and, when applicable, legal authority for implementation. Non-profit organizations' reactions to the lionfish invasion will be examined first, followed by those of regional fishery management councils, federal agencies, and inter-agency councils. This chapter will conclude by examining two of the few examples of lionfish response management plans.

Non-Profit Organization Responses

While in the United States non-profit organizations are subject to higher federal laws, they often work in conjunction with governing-agencies in order to carry-out federal and international policies. Additionally, in cases such as the lionfish invasion where very little legal action has been taken, non-profit organizations are able to exercise a great deal of power in terms of influencing those federal policies. Two of the most influential non-profit organizations in terms of their reaction to the lionfish

invasion are Reef Environmental Education Foundation (REEF) and the Caribbean Oceanic Restoration and Education (CORE) Foundation.

REEF's purpose is to "provide the SCUBA diving community a way to contribute to the understanding and protection of marine populations"[77]. The organization primarily achieves this goal through its REEF Fish Survey Project, which is a volunteer fish monitoring program[78]. Indeed, the data gathered from this program is used by the USGS to record lionfish sighting databases and range maps[79]. However, in response to the lionfish invasion, REEF has expanded its activities to include lionfish education, removal, and seafood marketing. REEF hosts lionfish workshops that educate resource managers on "detailed action plans for lionfish removal, how to encourage lionfish as a commercial fisheries and getting the community involved"[80]. Additionally, REEF hosts lionfish removal competitions called "Lionfish Derbies"; from 2009 to present, these derbies have been solely responsible for the removal of 6,528 lionfish (from U.S. and Bahamian waters)[81]. A final way in which REEF has responded to the lionfish invasion is by collaborating with other organizations, including NOAA to encourage public consumption of lionfish. The most recent product of these efforts is the publication of REEF's *Lionfish Cookbook* which includes dozens of recipes for lionfish, in addition to a

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[77] Reef Environmental Education Foundation. "About REEF". *Reef Environmental Education Foundation.* 2011. Key Largo, FL. http://www.reef.org/about/.

[78] Ibid.

[79] Reef Environmental Education Foundation. "Lionfish Research Program." *Reef Environmental Education Foundation*. 2011. Key Largo, FL. http://www.reef.org/programs/exotic/lionfish.

[80] Reef Environmental Education Foundation. "Lionfish Workshops." *Reef Environmenal Education Foundation*. 2011. Key Largo, FL. http://www.reef.org/lionfish/workshops.

[81] Reef Environmental Education Foundation. "Lionfish Derbies." *Reef Environmenal Education Foundation*. 2011. Key Largo, FL. http://www.reef.org/lionfish/derbies.

background on the lionfish invasions and instructions on how to safely catch and handle lionfish.

The CORE Foundation was created in response to the lionfish invasion. Its mission "is to advance the profession of marine stewardship to ensure the longevity, preservation and benefits of our Caribbean Sea."[82] CORE's primary method of marine stewardship is lionfish removal; it advocates public outreach and education initiatives as a key method of achieving goal. Additionally, CORE encourages "collaboration in lionfish management between other non-governmental organizations, scientists, and marine managers"[83] by participating in Caribbean Alliance programs and by aiding marine park managers in writing lionfish management plans.

Regional Fishery Management Council Responses

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), enacted in 1976, is the "primary law governing marine fisheries management in U.S. federal waters."[84] The act aims to both manage U.S. fisheries and promote conservation and emphasizes reaching conservation goals by "rebuilding overfished fisheries,

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[82] Caribbean Oceanic Restoration and Education (CORE) Foundation, *"About the CORE Foundation," Caribbean Oceanic Restoration and Education Foundation, 2011.* Christiansted, VI. http://nolionfish.com/about/.

[83] Jonathan Schram, "Policy and Management Options for Invasive Indo-Pacific Lionfish in U.S. Waters," MS thesis, Duke University, 2011.

[84] National Marine Fisheries Program. "Magnuson-Stevens Act". *National Oceanic and Atmospheric Administration*. 2010. http://www.nmfs.noaa.gov/msa2005/.

protecting essential fish habitat, and reducing bycatch."[85] The MSFCMA created eight regional fishery management councils, two of which pertain to (or could potentially pertain to) lionfish management strategies, the Caribbean Fishery Management Council (CFMC) and the South Atlantic Fishery Management Council (SAFMC).

The CFMC is responsible for creating fishery management plans (FMP) for U.S. fishery resources within the Caribbean Sea. After FMPs are created, the CFMC must submit them for approval by the US Secretary of Commerce. "Although there are no FMPs currently in place for lionfish, during the 1st Regional Lionfish Strategy Workshop in Cancun Mexico the CFMC was identified as a potential mechanism through which support and implementation for a regional lionfish plan could be founded"[86]. Additionally, the lionfish invasion may impact species for which there are FMPs and cause policy-makers to amend those existing FMPs in order to account for the impact of the lionfish. The SAFMC is responsible for managing the Snapper-Grouper complex[87] and established new policies in 2010 in reaction to the lionfish invasion's impact on the marine ecosystems under their stewardship. Their policy encourages the creation of National Aquatic Nuisance Species Task Force lionfish management plans, the creation of fishing gears that efficiently trap lionfish with little to no by-catch and minimal impact on the ecosystem, and amendments to FMPs to exclude lionfish from Fishery

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[85] Ibid.

[86] Schram, "Policy and Management Options for Invasive Indo-Pacific Lionfish in U.S. Waters".

[87] South Atlantic Fishery Management Council (SAFMC), "Policies for the Protection of South Atlantic Marine Ecosystems from Non-Native and Invasive Species," *South Atlantic Fishery Management Council,* 2010.

Management Units (FMUs)[88].

Federal Agencies

While there are several agencies that deal with the governance of U.S. oceans, the two that have most important in terms of reaction to the lionfish invasion are the NOAA Center for Coastal Fisheries and Habitat Research (CCFHR) and the U.S. Department of State Office of Oceans and Polar Affairs (OPA). One of the primary objects of the CCFHR is to provide "coastal resource managers with scientific expertise on issues such as habitat restoration, spatial planning, algal bloom ecology, and shoreline response to climate change"[89]. In response to the lionfish invasion, the CCFHR has become the principal scientific resource on the lionfish invasion for NOAA and the State Department. Additionally, CCFHR helps on a local level by educating the general public on the dangers and problems of lionfish, training scuba divers in lionfish-capture techniques, and supporting lionfish removal tournaments[90].

The OPA is charged with "formulating and implementing U.S. policy on international issues concerning the oceans, the Arctic, and Antarctica"[91]. One of OPA's primary objectives in terms of marine stewardship is protection against pollution and

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[88] Ibid.

[89] Schram, "Policy and Management Options for Invasive Indo-Pacific Lionfish in U.S. Waters"; NOAA's National Centers for Coastal Ocean Science. "National Centers for Coastal Ocean Science Strategic Plan: 2011-2015." *NOAA*. 2011.

[90] Schram, "Policy and Management Options for Invasive Indo-Pacific Lionfish in U.S. Waters".

[91] Office of Ocean and Polar Affairs, "Ocean and Polar Affairs", *U.S. Department of State,* 2011, http://www.state.gov/e/oes/ocns/opa/index.htm.

other threats, including that of invasive species. On an international level, the OPA acts as an educational resource for the lionfish invasion and participates in the Global Invasive Species Programme, "an international partnership that seeks to conserve biodiversity by minimizing the spread and impact of invasive species"[92]. Finally, the OPA works to coordinate domestic efforts for lionfish management.

Inter-agency Councils

The Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990 established the Aquatic nuisance Species (ANS) Task force, an intergovernmental organization charged with, among other things, regulating all aquatic nuisance species. This interagency task force is co-chaired by the US Fish and Wildlife Service (USFW) and NOAA and which comprises of thirteen federal agency representatives (16 U.S.C. § 4701 et seq.). In addition to coordinating government management of aquatic nuisance species, the ANS is also the authoritative agency to whom state and interstate ANS management plans must be submitted for approval (16 U.S.C. § 4701 et seq.). As of 2008, the ANS Task Force has acknowledged lionfish as "an ANS of serious environmental and social concern"[93].

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[92] Schram, "Policy and Management Options for Invasive Indo-Pacific Lionfish in U.S. Waters".
[93] Ibid.

Federal Management Plans

Presently, at the federal level, "there are no region-wide management plans for invasive lionfish in the coastal waters of the Southeast U.S.A., Gulf of Mexico, or Caribbean Sea."[94] However, there are a few pieces of federal legislation worth noting in terms of their potential to affect a national lionfish management plan. The National Marine Sanctuary Act (NMSA) has the authority to issue regulations "specifying the types of lionfish management activities in [Marine Sanctuaries]". Because there have been instances in which National Marine Sanctuaries have issued permits for the removal of lionfish from specific sanctuaries[95], it is possible that they could integrate such permitting practices into a national lionfish management plan.

The Endangered Species Act (ESA) calls for the protection and recovery of both endangered species and the ecosystems upon which they depend[96]. While, of course, the ESA would not call for the protection of lionfish, they could provide justification to improve lionfish control and eradication efforts. The Commerce Department's National Marine Fisheries Service (NMFS) is responsible for administering the ESA for marine wildlife[97]; because lionfish pose a threat to many species protected by the ESA, it is probable that the NMFS will apply pressure to other organizations to develop and improve lionfish management plans.

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[94] J. A. Morris Jr. and P.E. Whitfield, *Biology, Ecology, Control and Management of the Invasive Indo-Pacific Lionfish: An Updated Integrated Assessment*, NOAA Technical Memorandum NOS NCCOS 99, 2009.

[95] National Marine Sanctuaries, "Sate of the Sanctuary Report Protection and Management," *NOAA*, 2010. http://sanctuaries.noaa.gov/report2009/resource.html.

[96] U.S. Fish & Wildlife Service, "Endangered Species Program," *FWS*, 2011. http://www.fws.gov/endangered/laws-policies/.

[97] Ibid.

In March of this year, a resolution calling for national awareness and action in regards to the lionfish invasion was submitted to Congress (H.RES.132.IH). The resolution calls for "the development of a comprehensive, scientifically based, region-wide strategy, including local management plans and international partnerships, to address the lionfish invasion in the Atlantic Ocean" and also "encourages raising public awareness about the lionfish invasion across the United States and its territories through outreach and education"[98]. U.S. Virgin Islands Delegate Donna Christensen submitted the bill to Congress and although it brought congressional attention to invasive lionfish issues, the bill was recalled by full committee on September 1, 2011.

Examples of Lionfish Management Plans

The Florida Keys National Marine Sanctuary (FKNMS) and the U.S. Virgin Islands (USVI) have both created lionfish control and management action plans; in this paper, I examine the different objectives and strategies of each of these plans. The FKNMS lionfish action management plan aims to:

> Detect and control Lionfish abundance in the FKNMS; identify and prioritize FKNMS marine zones requiring vigilant Lionfish control; promote and build public awareness of the damaging ecological impact of Lionfish; promote protection and sustainable use of Sanctuary resources; facilitate uses of the Sanctuary that are consistent with resource protection; and ensure coordination

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[98] "H. Res. 132—Summary," *Congressional Research Service*, 2011. http://www.govtrack.us/congress/bill.xpd?bill=hr112-132&tab=summary

and cooperation between Sanctuary managers and other Federal, state, and local authorities with jurisdiction within or adjacent to the Sanctuary.[99]

In order to achieve these goals, FKNMS proposes to produce and distribute outreach information, implement lionfish collection and handling training, issue permits to remove lionfish from the sanctuary, coordinate early detection with rapid response, develop measures to evaluate success in order to maximize efficiency of strategies, and identify data needs in order to better forecast lionfish spread and impacts[100]. Because this paper focuses on policies regarding lionfish removal, let us look specifically at FKNMS's proposal to issue lionfish removal permits. In the early stages of invasion, the FKNMS issued letters of authorization (LOA) to a few individuals allowing them remove lionfish from no take areas (although the gear restrictions applied). The plan for the current stage of invasion (intermediate) is to issue permits to trained responders to remove lionfish from no-take areas (again, gear restrictions apply). If the invasion reaches to the advanced or established stage, the FKNMS will reevaluate permitting requirements and may adjust gear restrictions in order to improve efficiency of lionfish collection.

The U.S. Virgin Islands' Lionfish Response Management Plan (LRSM) aims to achieve "a sustained reduction of the lionfish population throughout the USVI through: education, outreach, and training; opportunistic and targeted detection and removal of

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[99] Morris and Whitfield, *Biology, Ecology, Control and Management of the Invasive Indo-Pacific Lionfish*.
[100] Ibid.

lionfish; monitoring and data gathering; data analysis and reporting."[101] The ultimate goal of this management plan is to remove lionfish whenever they are sighted. At the moment the response plan for the USVI depends upon where the lionfish is sighted. If a lionfish is sighted outside of National Parks and Monuments, anyone familiar with methods for safely killing or capturing lionfish and has the appropriate equipment is allowed to remove it; the sighting should be reported to authorities regardless of if the specimen was killed/removed. Any lionfish sighted within the boundaries of National Parks and Monuments should be reported to authorities, but no specimens may be removed without a research collection permit. Finally, if a lionfish is sighted in the St. Croix East End Marine Park (EEMP), anyone with a permit may kill or remove lionfish specimens; the Department of Planning and Natural Resources Division of Fish and Wildlife and Coastal Zone Management issues permits to people who have received training in lionfish identification, removal, and reporting[102].

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[101] Barbara Kojis, "Lionfish Repsonse Management Plan US Virgin Islands," *USVI Department of Planning and Natural Resources*, 2009.

[102] Ibid.

Chapter Five: Analysis of Policy Reactions to the Lionfish Invasion

There are four general trends that can be identified from the marine policy reactions to the lionfish invasion discussed in the previous chapter: a call for more education and public outreach initiatives, a call for greater interagency/inter-institute cooperation, implementation of lionfish removal programs (where applicable), and the promotion of lionfish for seafood consumption. This chapter evaluates these different trends by identifying their potential to achieve their aims as well as any possible negative repercussions.

Education and public outreach are essential for the success of any lionfish management initiative. Indeed, almost every management plan recognized the necessity of this objective. However, the fault in outreach initiatives corresponds to the issue of interagency/inter-institute cooperation. While the CORE, the OPA, the ANS task force, and both the USVI and FKNMS all call for greater cooperation between agencies in order to better coordinate lionfish education and removal efforts, it seems that all of these organizations are simply recognizing the problem rather than working towards its solution. Because the financial resources of all of these different organizations are finite, each organization can devote only a small portion of its funds to education and public outreach initiatives. This results in a large number of smaller-scale and lower-quality education materials and outreach programs. However, the efficiency and effectiveness of these public education projects could be noticeably

improved if one organization were to be assigned primary responsibility for creating materials for education and outreach initiatives. Because it is already recognized as the preeminent leader in scientific expertise on the lionfish invasion in the U.S., it seems most logical for NOAA's CCFHR to take on this particular task of producing outreach materials. With the support of other organizations (financially and otherwise), the CCFHR could produce a national public outreach plan as well as provide high-quality educational materials and training for individual sites/organizations. Having one unified lionfish awareness outreach plan has the potential to be much more effective than several disjointed efforts.

Lionfish removal programs are the riskiest component of lionfish management plans in terms of potential for success balanced against potential damaging consequences. On the one hand, these removal programs offer a method through which the lionfish population could be kept in check without running the risks associated with promoting lionfish for popular consumption (discussed later in this chapter). If a lionfish is spotted outside of a marine reserve, the general consensus (of the policies discussed in the previous chapter) is that a person should kill or remove the specimen as long as he or she has the knowledge and tools to handle lionfish. However, the riskiest lionfish removal policies are those that grant permission of some sort (through letters of permission, licensing, etc.) to remove lionfish from marine reserves (see both examples of lionfish management plans described in Chapter Four).

First of all, by allowing lionfish to be removed from an otherwise 'no-take' marine reserve, reserve managers run the risk of having people killing or removing

(accidentally or otherwise) other, protected species within the reserve. Presumably a reserve would not have the resources to send a law enforcement agent out with every person hunting lionfish to ensure that only lionfish were removed from the reserve. Additionally, by making an exception to the 'no-take' rule, reserve managers weaken the 'no-take' policy of the reserve. Making exceptions to the rules confuses users of the marine reserve and also leads them to believe that the laws of the reserve, as well as consequences for breaking those laws, are lenient.

The alternative to licensing users to remove lionfish from a reserve is to limit the population of people allowed to remove lionfish to only employees of the marine reserve. In this scenario, any non-employee would be asked to report any lionfish sightings and then a member of the marine reserve staff would later be dispatched to attempt to find and capture the specimen. There are three major problems with this scenario: it limits the possibility of opportunistic removal, it reduces the number of lionfish that will be removed, and it drains reserve resources. Because under this scenario non-employees are required to report lionfish sightings as opposed to capturing the lionfish when they have the chance, the number of lionfish actually removed from the reserve will decline. The lionfish(s) reported by non-employees will inevitably have a significant amount of time to change locations before a reserve employee manages to come out and remove it. Finally, limiting permission to remove lionfish to only reserve workers will drastically increase the costs of the marine reserve because it will have to pay for workers to remove lionfish instead of having users of the reserve remove them for free.

Reserve managers must carefully weigh the benefits of licensing lionfish removal with the costs of such a removal program. An optimal solution would be to encourage lionfish removal immediately outside the borders of the reserve (which could both limit the number of lionfish that enter the reserve as well as remove any lionfish that venture outside of the reserve) and place lionfish traps inside of the marine reserve. While research still needs to be done in order to develop and perfect a device that catches lionfish with minimal effect on other organisms, the benefits of such a device (e.g. lowered cost of maintaining the reserve, maintaining a 'no-take' policy for general users and by doing so, maintaining strength of reserve regulations) would likely balance and even outweigh the cost of its development.

The promotion of lionfish as a food for popular consumption is seen by many as a neat and effective solution to the lionfish invasion problem. If lionfish gain popularity among chefs and consumers, the demand for lionfish meat would not only reduce the lionfish population in the Atlantic/Caribbean, but in doing so, it could also decrease the pressure on target species such as the Nassau Grouper. More people eating lionfish could lessen the demand for grouper as an item for consumption and it would also reduce the grouper's competition for food (since lionfish and grouper occupy similar ecological niches and consume many of the same foods); these combined forces could help the grouper population return to a more sustainable level. Additionally, if demand for lionfish increases, the costs of removing lionfish from the Atlantic and Caribbean would no longer lie almost exclusively on the shoulders of the government and non-profit organizations, but it would be largely shared by the private sector.

Indeed, if demand for lionfish meat reaches the level of demand for that of grouper and snapper, the problem of lionfish invasion may very well take care of itself.

Although marketing lionfish for seafood consumption seems like a completely ideal solution, critics raise two major points of concern. The Nature Foundation recommends that lionfish not be widely touted as an edible species because they have found that an "uncomfortably high" percentage of specimens tested have ciguatoxin, the toxin that causes Ciguatera poisoning[103]. Indeed, instances of Ciguatera poisoning, the illness most commonly associated with eating barracudas, will cause serious problems for movements such as NOAA's "Eat Lionfish" campaign.[104] However, perhaps all is not lost. Lionfish testing positively for ciguatoxin, for now at least, are only found in waters off of the coasts of St. Maarten and the U.S. Virgin Islands. It should be noted that high levels of ciguatoxin are the result of high levels of the toxin occurring in that particular area of the ocean; indeed, ciguatoxin occurs in more species than just lionfish and barracuda and is more dependent upon area of the ocean than species of fish. Few if any instances of Ciguatera poisoning have been reported in lionfish caught off of U.S. mainland coasts and there have been no incidents reported in the Dominican Republic, Cayman Islands, Belize, Jamaica, and the Bahamas; NOAA and other non-profits still encourage popular consumption of lionfish in the United

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[103] "Nature Foundation Recommends Population not eat Lionfish; Study shows toxins found in Lionfish caught in St. Maarten Waters," *St. Martin News Network,* 21 November 2011. http://www.smn-news.com/st-maarten-st-martin-news/8208-nature-foundation-recommends-population-not-eat-lionfish-study-shows-toxins-found-in-lionfish-caught-in-st-maarten-waters.html.

[104] NOAA, "NOAA: More Fishing, Higher Consumption Might Help Reverse Lionfish Invasion," *NOAA News*, 06 August 2010. http://www.noaanews.noaa.gov/stories2010/20100806_lionfish.html.

States[105]. Another concern associated with the promotion of lionfish as a seafood consumption item is that the U.S. could become dependent upon lionfish, which could lead to "illicit future introductions of lionfish into U.S. waters, with the purpose of helping sustain an economic dependence on an ecologically harmful invasive species"[106].

Lionfish management plans correctly identify four major objectives for controlling the lionfish invasion: public outreach, interagency and inter-institute cooperation, lionfish removal programs, and the promotion of lionfish for consumption. However, in order to maximize effectiveness and efficiency of managing the invasive lionfish population, education and outreach efforts should come from one unified source, individual marine reserve managers should carefully weigh the costs and benefits of a licensed lionfish removal program and consider alternative solutions before initiating such a licensing program, and the U.S. Food and Drug Administration should carefully monitor ciguatoxin levels to minimize any health risks associated with lionfish consumption.

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[105] Timothy O'Hara, "Experts: Local lionfish safe and tasty," *KeysNews*, 30 November 2011. http://keysnews.com/node/36290.

[106] Schram, Jonathan. "Policy and Management Options for Invasive Indo-Pacific Lionfish in U.S. Waters." MS thesis. Duke University, 2011;
Morris and Whitfield. *Biology, Ecology, Control and Management of the Invasive Indo-Pacific Lionfish*.

Chapter Six: Lionfish "Management", an Ethical Perspective

"Yet you, my creator, detest and spurn me, thy creature, to whom thou art bound by ties only dissoluble by the annihilation of one of us. You purpose to kill me. How dare you sport thus with life?"

Mary Shelley, *Frankenstein*

Thus far, I have discussed the lionfish invasion, its horrible repercussions on Atlantic and Caribbean marine habitats, and policy responses to the invasion. However, before concluding, I think it is important to discuss lionfish management plans from an ethical perspective. As various government agencies prepare management plans and strategies to, if not eradicate, at least control the invasive lionfish population, the question remains: should they?

As mentioned in Chapter Two, lionfish pose a serious threat to biodiversity; indeed, one study considers them to be "one of the top fifteen global threats to conservation biodiversity"[107]. Consider the significance of this assessment—even though the lionfish invasion is limited to the coasts of the Western Atlantic and Caribbean, it is considered to be one of the top fifteen threats to *the world's* biodiversity. This classification might seem extreme, but it is perhaps justified when one considers that studies have shown that a single lionfish can reduce reef fish populations on a reef by almost 80 percent[108] in only five weeks. There is no question that invasive lionfish pose a severe threat to the existing balance of U.S. marine ecosystems and, in terms of

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[107] Sutherland et al., "A horizon scan of global conservation issues for 2010."

[108] Albins and Hixon, "Invasive Indo-Pacific lionfish *Pterois volitans* reduce recruitment of Atlantic coral-reef fishes."

controlling the lionfish population to protect that balance, lionfish control management plans are justified. Because of their destructive nature, lionfish have been deemed "killable".

Before too hastily condemning the lionfish invasion and advocating for their eradication, let us first consider how humankind has affected our own environment. We cannot, without being unforgivably hypocritical, declare invasive species 'killable' based on the fact that they destroy of the environment when in fact we humans are the most destructive force in nature. Furthermore, the very idea of a "non-native" species rests upon the incredibly subjective definition of what constitutes a "native" species: "species which have auto colonized an area since a selected time in the past"[109]. The relativity of time and space really makes the fairly arbitrarily defined "invasive" species one that simply happens to be in the wrong place at the wrong time.

Additionally, we should note that lionfish are deemed "destructive" largely because they threaten the species that we, human consumers, deem valuable. Their introduction inevitably aids *some* populations of the marine environment (e.g. the microorganisms upon which lionfish prey feed). To demonstrate these points, let us consider the following example: species A, introduced in 1950 might be considered an aggressive invasive species because it substantially harms the population of species B, which has existed in a particular country (let us say that country is Costa Rica) since 1700. However, what if species C has existed in Costa Rica since the end of the Ice Age

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[109] C. Warren, "Perspectives on the 'alien' versus 'native' species debate: a critique of concepts, language and practice," *Progress in Human Geography* 31 no. 4 (2007): 427-446.

and the introduction of species A actually helps restore the struggling population of species C? Depending on one's parameter of time, species A can be said to either harm native species or help them (or, perhaps one might concede that it does both). Additionally, one's definition of *where* also determines whether or not a species should be considered invasive. Continuing with our example, let us say that species A was actually found in Central America as early as the 1500s but it wasn't until the 1950s that it actually came to Costa Rica. This example demonstrates that one's definition of a 'selected area' largely determines whether or not a species can be considered 'native' or 'alien'. Obviously, the terms 'native' and 'alien' species are relative terms rather than clear-cut categories.

All of the organizations mentioned in Chapter Four seek to preserve the delicate balance of U.S. marine ecosystems. REEF's purpose is to "To conserve marine ecosystems for their recreational, commercial, and intrinsic value"[110]. The SAFMC is responsible for "the conservation and management of fish stocks within the federal 200 nautical mile limit off the coasts of North Carolina, South Carolina, Georgia, and east Florida to Key West."[111]. The national system of Marine Protected Areas exists "to protect important habitats and resources."[112] However, in pursuing lionfish removal policies, all of these organizations do not entirely remain true to their mission.

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[110] REEF. "About REEF".
[111] "South Atlantic Fishery Management Council". *SAFMC.* http://www.safmc.net/.
[112] NOAA, "National MPA Center."

In advocating that as many lionfish as possible should be eradicated from the Atlantic and Caribbean, these organizations are not necessarily concerned with conserving marine ecosystems as much as they are with concerning *our idea* of what a marine ecosystem should be (an idea based on perhaps a few decades of experience). Indeed, Sarah Whatmore points out, "the treatment of the wild as a pristine exterior, the touchstone of an original nature, sets the parameters of contemporary environmental politics"[113]. Humans have a very specific idea of what nature is: one, pristine, unchangeable entity. 'Native' species are integral to its existence whereas invasive species do not belong and threaten its very viability.

Mark Gardener, a researcher on the Galapagos Islands (one of the most pristine ecosystems in the world) has the right idea in saying, "It's time to embrace the aliens"[114]. While conservation organizations spend millions of dollars trying to remove 'invasive' species, their efforts prove to be increasingly costly and futile. Gardener suggests that instead of trying to eradicate potentially harmful invasive species, we instead make our goal limit their numbers so that they do not overwhelm the native population. Furthermore, if the invasive species is benign, Gardener suggests that we simply accept it as a 'new native'.[115]

Gardener's is a more appropriate strategy than those currently being pursued by U.S. marine reserve managers. Gardener's management plan for invasive lionfish in

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[113] Sarah Whatmore, *Hybrid Geographies: Natures, Cultures, Spaces*. SAGE, 2002.
[114] G. Vince, "Embracing Invasives," *Science* 331 (2011): 1383.
[115] Ibid.

the U.S. would include policies that would reduce the lionfish population only to the extent that "native" species are able to coexist. Most likely, this strategy would employ a quota system, which would allow a certain number of lionfish to live on specific reefs. However, we are still left with the pesky issue of killability. Are humans entitled to kill as many lionfish as we can in the name of "protecting" our marine ecosystems? Lionfish threaten the balance of the ecosystem because of their superb natural hunting abilities and protective mechanisms. Is that not exactly how survival of the fittest and evolution occur? A new predator is introduced, and the populations in the ecosystem adapt and evolve. Why should humans interfere with the very process that made us king of the food chain? Arguably, we are morally obligated to interfere because "the unprecedented rate and scale of human-induced invasions has transformed 'what once was a catalyst for evolutionary invention [into] an over-whelming force for ecological destruction'"[116]. Just like Frankenstein, we have created an evil monster and we must now try to subdue it.

However, just because humans have an obligation to manage the destructive force of the invasive species that we ourselves introduced (intentionally or otherwise) does *not* give us a license to kill. Instead, we should focus our energies on finding a way to control invasive species populations through a more natural method. Lionfish have no real predators in their invasive habitats; however, rather than encourage people to try and kill as many lionfish as possible, we should first examine *why* it is that they have no predators in the Atlantic/Caribbean. The grouper is one of the lionfish's only

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[116] Warren, "Perspectives on the 'alien' versus 'native' species debate."

predators, and the lionfish's proliferation in its newfound habitat is due to both the lack of grouper and the excess of the surplus of resource availability (due to low grouper populations). Why is it that grouper populations are so low in these areas? Because humans have overfished them to the extent that many are now threatened with extinction. Rather than use precious time and resources to kill lionfish, we should focus our attention on rebuilding the grouper population and, in doing so, restoring a more 'natural' environment in which evolution can occur. Policy-makers should look towards more natural methods of restoring the ecosystem rather than automatically assuming that the destructive nature of this invasive species gives them a license to kill. Humans should repair the damage that *we* cause (indirectly or otherwise) to the environment in introducing destructive invasive species; however, we should not use more destruction as a means to achieve our goals, but rather we should aim to more naturally mimic the biological processes that created this ever-evolving natural world we all share.

This solution, however, is one that exists only in a utopian world. Human demand for fish shows no signs of decreasing; it therefore seems unlikely that we will ever be able to restore the grouper population to a level at which it can contain the lionfish population explosion. The compromise between ethics and practicality? Eat lionfish. Killing lionfish for the sake of preserving our idea of what a marine ecosystem "should be" is hypocritical. Killing lionfish and simply disposing of them, in light of the chilling decline in global fish stocks, is unethical. Killing lionfish and eating them relieves consumer pressure put on other highly in-demand fish. By decreasing demand

for other species, eating lionfish can help restore global fish stocks.

Of course, it is important to continually monitor toxin levels in lionfish to ensure that they are safe for human consumption. However, barring any drastic changes in toxin levels of U.S. coasts, we should be able to safely consume lionfish for some time. The other concern with eating lionfish voiced by some policy makers is that creating consumer demand for lionfish might result in lionfish being purposefully introduced into U.S. waters. So what? Because they already exist in such large populations, the only reason that more lionfish would have to be introduced into U.S. waters would be to meet consumer demand for them. Therefore, it is safe to conclude that in this scenario, the human population is keeping the lionfish population in check and consequently the destruction of marine life caused by lionfish is minimal. The other reason that policy-makers dislike the purposeful placing of invasive lionfish into U.S. waters is that they are just that, an invasive species. Government agencies and policy-makers must overcome their wildlife xenophobia and embrace the opportunity with which they are presented, an opportunity to alleviate fishing pressure on endangered species by supplementing consumer demand with lionfish.

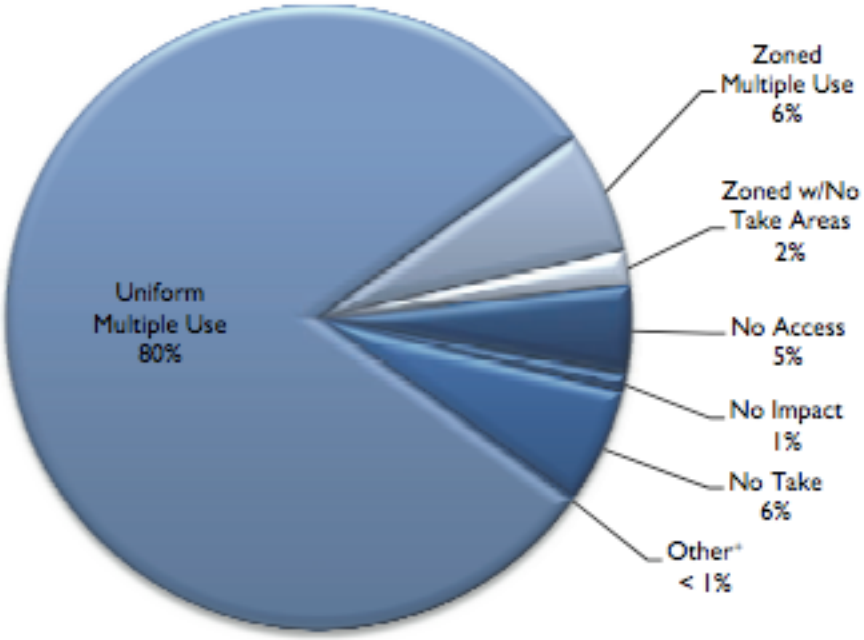
Conclusion

Scientists and policy-makers are sincerely concerned with the rapid expansion of the indo-pacific lionfish throughout the southeastern U.S. coast and the Caribbean. Lionfish have virtually no natural predators (though grouper and sharks have been known to eat them on occasion) and, as naturally skillful predators themselves, are capable of causing great damage to the marine ecosystems they invade. Lionfish are a particularly troublesome problem for marine reserve managers because many MPAs prohibit the removal of anything within the reservation.

Many different organizations and institutions, from non-profits to the federal government, are concerned with controlling the lionfish invasion. Marine policy responses can be categorized as having four general initiatives: public education, interagency cooperation, lionfish removal programs, and the promotion of lionfish for consumption. Of these, lionfish removal programs, particularly within marine reserves, pose the most serious problems financially, logistically, and ethically. While lionfish removal programs claim to act in the name of preserving 'nature', it is perhaps more apt to say, in light of the fact that nature is ever-evolving, that such removal programs aim to preserve our *idea* of nature. Nevertheless, marketing lionfish as an item for consumption could not only control the lionfish population, but it could also help alleviate fishing pressure on many declining and valuable fish stocks.

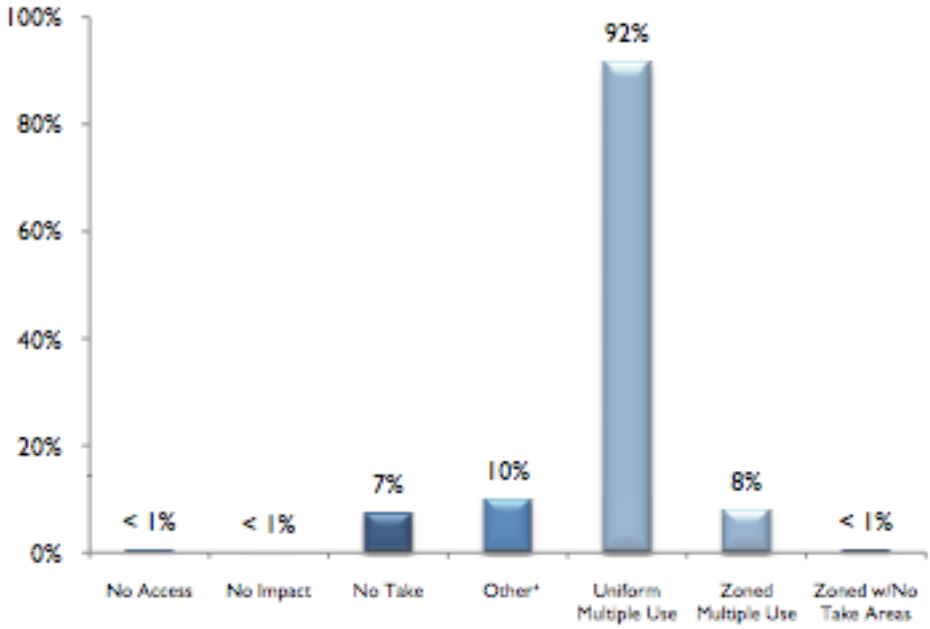
Appendix A. "Breakdown of Marine Protected Areas by Level of Protection and by Level of Government"

Figure 1: Percentage of MPA sites by Level of Protection



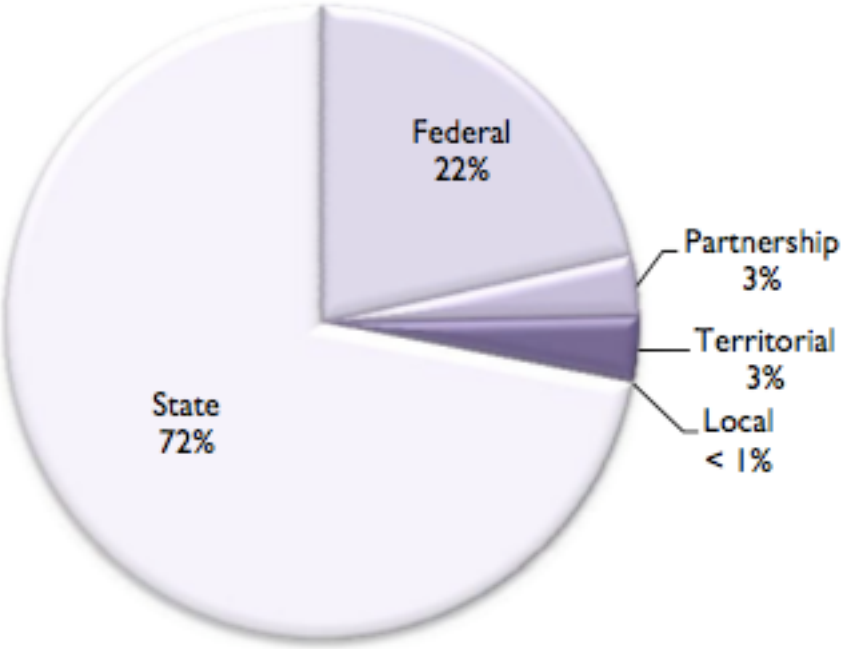
(Source: www.mpa.gov)

Figure 2: Percentage of MPA areas by Level of Protection



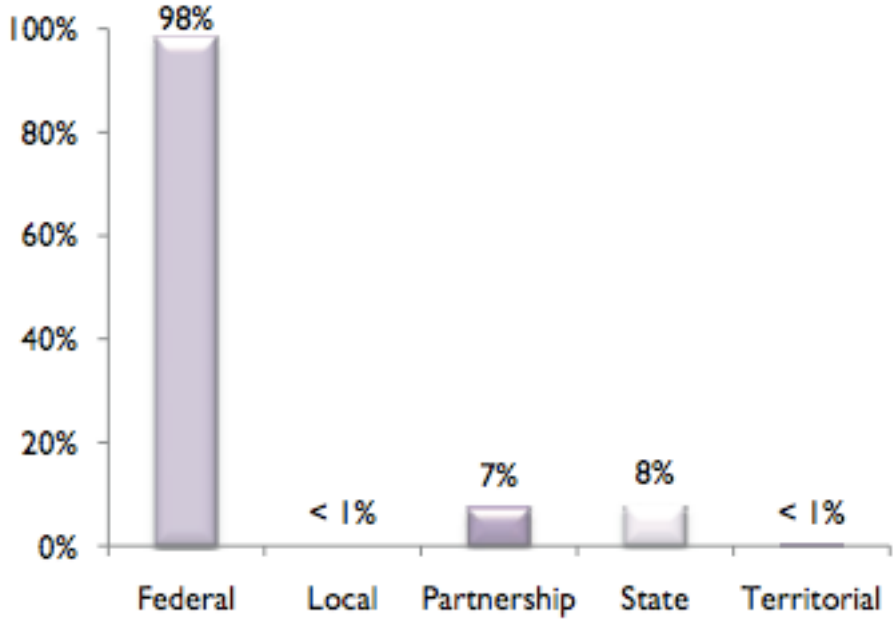
(Source: www.mpa.gov)

Figure 3: Percent of MPA Sites by Level of Government



(Source: www.mpa.gov)

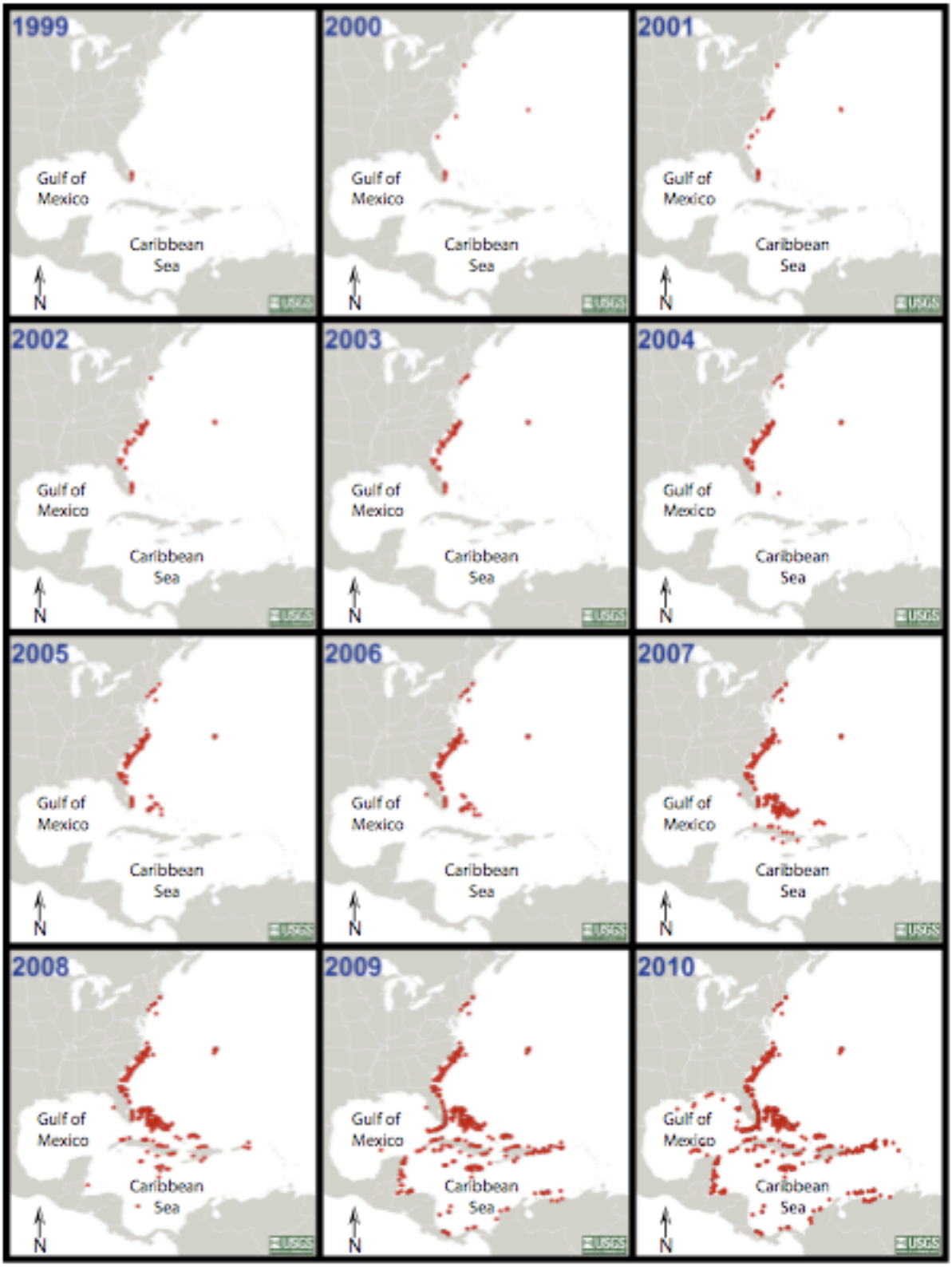
Figure 4: Percent of MPA Areas by Level of Government



(Source: www.mpa.gov)

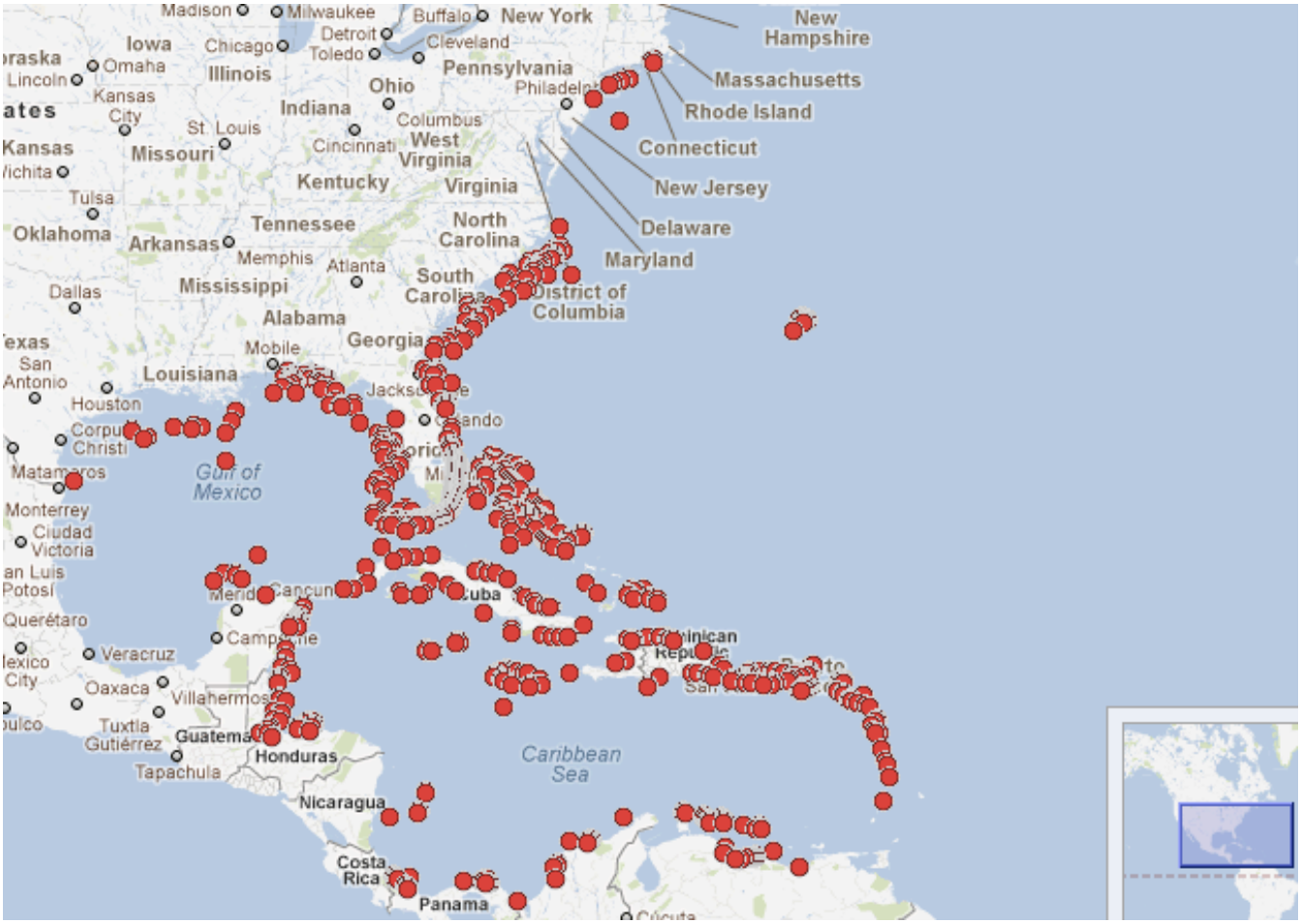
Appendix B. "Lionfish invasion of the Western Atlantic and Caribbean

Figure 1: Chronological occurrences of lionfish in Western Atlantic as of 2010.



(Sources: Schofield, 2009 (data from 1999-2009) and Betancur-R, 2011 (data for 2010).)

Figure 2: Lionfish distribution in the Western Atlantic as of December 2011.



(Sources: NOAA, REEF, U.S. Geological Survey. 2011)
(http://nas.er.usgs.gov/taxgroup/fish/lionfishdistribution.aspx)

Appendix C. "Lionfish Images"

Figure 1. Side view of Lionfish.

(Source: B. Clear, CEI)

Figure 2: Front view of Lionfish

(Source: Roger Greenway, Environmental News Network)
(http://www.enn.com/wildlife/article/41636)

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