

The Benefits of Culling, Consuming, and Banning Live Imports as Methods of Controlling Lionfish Populations

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Abstract: *The invasive species *Pterois miles* and *Pterois volitans*, better known as lionfish, have created the need for vast efforts to control their populations in Florida. Many solutions have been discussed, including: training reef sharks to prey on lionfish, expanding the culinary market, banning imports, and culling (Culling is targeting a specific species with a goal of reducing its population). This paper argues that culling is the most effective because it is the most the most widely researched solution out of the four, it has been seen to work in multiple studies, and people are currently working on ways to mitigate the negative effects of culling. While culling is the most effective method individually, implementing and maintaining a combination of multiple solutions will allow for the most effective results. Determining the most effective method of eradicating invasive lionfish is important (particularly for fishermen and private organizations in Florida) because lionfish are consuming dangerous amounts of fish in the Florida reef systems and destroying the environment. There are a variety of ways that culling could be implemented, from government agencies to private organizations.*

Keywords: Lionfish, culling, environment, wildlife, ecosystems

Introduction

Lionfish are gorgeous creatures. Growing up to 18 inches long as adults, lionfish are covered in maroon and white bands. Their fan-like dorsal and pectoral fins combined with small tentacles located above their eyes and below their mouths make them truly a unique species, but these little fish are more destructive than one might expect. The 18 spines protruding from their fins are what make them enticing, however, the spines are also filled with toxins ready to paralyze and potentially kill anything that gets too close.

Lionfish are native to the Indo-Pacific region but are now found all throughout the west Atlantic. With no natural predators to keep their populations in check, lionfish are destroying the ecosystems in the areas they are invading. Since the mid-1980s, the growing invasive lionfish populations in Florida reefs have been destroying the local ecosystems (Fears, 2014). The ecological damage caused by lionfish in Florida is a major issue because

lionfish feed on snapper, grouper, and other popular Florida fish, which can have a significant impact on the fishing industry ... One of the top species harvested in Florida is the red grouper ... which competes with the lionfish for prey, and is often prey itself. (Linares, 2015, p. 2)

In addition to lionfish preying on the native species in the Atlantic, the larger and most commonly consumed fish in Florida have limited food supply due to lionfish eating habits. Both of these factors drastically decrease the populations of fish targeted by commercial fishers and have negative implications for the Florida and U.S. economies. Red grouper alone accounted for \$15.1 million in Florida's dockside harvest in 2010-2011 (Linares, 2015, p. 2). If the invasive lionfish populations are not kept in check, native fish populations, including the red grouper, will continue to decline, causing a decrease in revenue from fisheries. The Florida economy relies on the native marine species for commercial fishing as it contributes to a large portion of their economy. As reported by the Florida Fish and Wildlife Conservation Commission (FWC), during the 2019-2020 fiscal year, recreational saltwater fishing alone generated a revenue of \$9.2 billion (Florida Fish, 2021). When combined with freshwater recreational fishing, the total revenue increases to \$13.8 billion (Florida Fish, 2021). The FWC also reported recreational fishing supported a total of 120,000 jobs throughout the state (Florida Fish, 2021). Should the Florida reef ecosystems continue to decline to the point where commercial fishing is no longer profitable, or even possible, thousands of Florida residents will

be forced out of their jobs. While many methods are currently in use to reduce the number of lionfish in the Atlantic and their impact on the environment, citizens and private businesses should consider a combination of solutions with an emphasis on culling to be the most effective method of controlling lionfish populations.

Background

Lionfish are native to the Indo-Pacific waters, but they can be found in aquariums worldwide. In the 1980s, lionfish were introduced to the Atlantic (Fears, 2014). Many scientists including Sarah Gallagher (2013) believe lionfish were introduced to the environment in one of two ways. Gallagher suspects lionfish were released into the south Florida waters by private owners, or they were accidentally introduced to the environment due to a hurricane destroying an aquarium by the coast (p. 1). Since then, the fish have been expanding from Florida to up the Atlantic coast, down into the Caribbean, and into the Gulf of Mexico. These fish are expanding their territory at aggressive rates due to three main reasons: their “unusually large spawning rates, broad eating patterns, and aggressive predatory features” (Gallagher, 2013, p. 2). Lionfish have no specific season in which they reproduce, and can reproduce every three to four days (Gallagher, 2013, p. 2). Additionally, these fish are especially adept at adapting to different habitats down to 10 degrees Celsius (Gallagher, 2013, p. 3). All of these factors are what allow lionfish to be such successful invaders.

Lionfish spines are a defense mechanism that protects them against predators, so few species in the world can consume these fish without dying. Since lionfish are not native to the Atlantic, virtually no species prey on them; this makes them very dangerous for the balance of ecosystems in the Atlantic. In addition, an individual fish can lay up to two million eggs per year, and while some eggs do not survive into maturity, the majority “escape predation due to a repellent occurring in the fertilized

egg mass. This means that huge percentages of lionfish fry (juvenile) will recruit to the safety of structure and mature with little predatory stress” (Harrel & Lowe, n.d.). This allows for lionfish populations to grow exponentially, even in their native habitats where they have predators. Having no natural predators in areas where they are invasive allows lionfish to grow and reproduce without any threat to their survival. This, combined with the fact that lionfish can “consume 8.9% of its body mass per day based on field observations”, means they can very easily destroy an ecosystem (Steell et al., 2019). In his paper, Plumer (2014) estimates lionfish “can eat up to 79% of juvenile fish in a reef in just five weeks”. Lionfish have reduced the native species’ populations so much that many are resorting to cannibalism due to a lack of food (Pyzyk, 2015). In addition to this, Green et al. (2012). and her colleagues conducted a study in 2008 surveying the effect of invasive lionfish on a stretch of reef in the Bahama’s . They found the lionfish were mainly consuming 42 species of fish in the reef. In just two years, Green et al. (2012) reported a combined 65% loss of biomass among the 42 species. An effective solution must be found to reduce the invasive lionfish populations and restore the natural balance to Florida marine life.

Training Reef Sharks

One potential solution to managing the lionfish population in Florida is training reef sharks to eat them. Reef sharks appear to be one of the only organisms that can eat lionfish unharmed, especially in areas where lionfish are invasive (Fears, 2014). One of the scientists in charge of the effort, Andrés Jiménez, saw the reef shark’s ability to successfully eat these fish and decided to take advantage of it by using spears to capture the lionfish and hand-feed them to reef sharks. This solution is beneficial because once the sharks begin to hunt lionfish naturally, it will offer a hands-off solution that costs no money to keep the lionfish population under control.

Unfortunately, downfalls to this solution are evident. As cited in Fears (2014), it is explained that sharks will begin assuming every diver they encounter has food for them. This could pose potential dangers for divers in areas where reef sharks feed on lionfish. Andrés Jiménez even admits if a lionfish escapes a shark's clutches, more often than not, the shark will start looking for the prey everywhere, and in this quest they . . . sometimes hit divers with the nose, or can even try to bite the spear, the rocks where the lionfish is hiding, or the cameras. Then the situation sometimes gets out of control. (quoted in Fears, 2014)

In addition to posing threats to divers, the sharks have not changed their natural diet when no divers are around (Fears, 2014). They mostly only eat the dead or injured lionfish fed to them by the divers and have not been seen to hunt live lionfish on their own (Fears, 2014). Not much research has been done on the effectiveness of this solution, and few reliable sources can be found that discuss feeding lionfish to reef sharks. Researcher for the Environmental Conservation Organization, Justin Grubich, stated: "training reef sharks is a questionable methodology" (personal communication, 4/27/2021). In an interview, Grubich explained "anecdotal success [was seen] in the Caribbean... [but] that won't necessarily work here in Florida simply because we don't have Caribbean reef sharks left in Florida. The only other sort of shark that might be interested is bull sharks" (Personal Communication, 4/27/2021). Using bull sharks in place of Caribbean reef sharks is not a popular idea because bull sharks are extremely unpredictable and have proven dangerous for humans, especially when it involves hand-feeding them. While in theory this solution is effective and efficient, in reality it puts people in dangerous situations.

Expanding the Culinary Market

Scientists including Amanda Nally and Sarah Gallagher also suggest creating a culinary market for lionfish to help reduce their effects on the environment. While many people are

not aware of this, lionfish are an edible species of fish. Once their toxic spines are removed, “they’re easy to filet, those who eat them say” (Waymer, 2014). One of the biggest hurdles with using the culinary market to effectively control the lionfish populations throughout the Atlantic is spreading knowledge of it and generating interest. Initially, not many people knew lionfish were edible but Amanda Nalley “has traveled [around Florida] for the last six years trying to get out the word about the voracious predator fish that thrive in the northern Gulf of Mexico and destroy native fish species” (Gabriel, 2017). Nalley’s efforts to increase awareness of the issues lionfish bring while expanding interest in implementing the species into the culinary market appear to be working. The FWChas seen an increase in interest eating lionfish from Florida residents. In addition to public interest increasing, commercial lionfish harvesting has increased followed by a significant decrease in lionfish sightings by divers in Pensacola reefs (Gabriel, 2017). If efforts similar to Nalley’s are made all across the Atlantic, similar results should be seen as well.

In another paper, Sarah Gallagher (2013) argues for expanding the lionfish culinary market and researched ways to use the market as a successful method of controlling the invasive lionfish populations. Part of her argument includes private organizations funding the culinary market and educating people about it. Her research revealed “through extensive advertising, fundraising, and educational outreach programs, the REEF [Reef Environmental Educational Foundation] organization has informed many locals and visiting tourists about the environmental and culinary benefits of lionfish consumption” (Gallagher, 2013, p. 15). If more private organizations were encouraged to promote the Eat-Lionfish campaign—a campaign created by the National Oceanic and Atmospheric Administration (NOAA) with a goal of “bringing together fishers, wholesalers, chefs and diners as active participants” in reducing the invasive lionfish populations (Graham, n.d., p. 2)—expanding

the culinary market would be an attractive method to decrease the Florida lionfish populations. This part of Gallagher's proposal would solve the question of who is funding the education and outreach for the culinary market. Current research by Gallagher and the FWC shows that so far, this method is effective.

The expansion of a culinary market for lionfish is an attractive method for controlling the lionfish population; however, drawbacks must be discussed. One major downfall to this solution is the fact that lionfish are difficult to mass harvest in the wild (Waymer, 2014). Due to the lionfish's spines, this species of fish must be caught by individually spearing each fish, which is labor intensive. Consuming lionfish may also prove to be harmful to humans because some contain harmful toxins released by dinoflagellates (Harmful Algal, n.d.). Dinoflagellates are dangerous to consume due to the neurotoxins they release including yessotoxin and palytoxin (Wang, 2008). These toxins are dangerous to consume because they interfere with nervous system pathways and can induce "gastrointestinal, neurological, cardiovascular and general symptoms" (Wang, 2008). The FDA "recommended to primary seafood processors that they should minimize ciguatoxic fish poisoning (CFP) risk by not supplying lionfish for consumptive purposes" (Gallagher, 2013, pp. 15-16). CFP, also called Ciguatera, is "an illness caused by eating fish that contain toxins produced by a marine microalga called *Gambierdiscus toxicus*" (Harmful Algal, n.d.). This illness is a concern for the Food and Drug Administration (FDA) because, while the symptoms are treatable, no current cure is available for it.

Gallagher argues the methods used for data collection and, therefore, the results of the study were questionable due to the fact that the tested lionfish were not collected from the same section of the reef (Gallagher, 2013, p. 15). The reliability of the results decrease because the fish were collected from different places. The inconsistent collection methods introduce confounding variables into the study. In addition to this, there is a

“lack of evidence that the level of ciguatera poisoning reported threatens humans, as the FDA have had no official reports of illness associated with the consumption of lionfish fillets” (Gallagher, 2013, p. 16). Although this is true, cases like this are associated with many other fish, including barracuda, black grouper, blackfin snapper, among others (Harmful Algal, n.d.). Since many cases have been reported with the species listed, cases of Ciguatera due to lionfish consumption are likely to be seen as well. Like many things, using a culinary market to control the lionfish population in the Atlantic is easier said than done.

Banning Lionfish Imports

Another solution for controlling the effect of lionfish on the Florida marine ecosystems is banning the importation of live lionfish. In June 2014, the seven commissioners of the FWC put this policy into effect and voted unanimously to stop all lionfish imports (Talbot, 2014). This policy was expected to be effective in decreasing the number of invasive lionfish because it limits the number of new fish released into the Florida waters in conjunction with divers continuing to hunt the preexisting invasive lionfish (Waymer, 2014). Implementing this policy would cut off the problem at the source. Banning imports would allow conservation programs to focus their time, money, and efforts on healing the environment the lionfish left damaged rather than combating the growing lionfish populations, decreasing native species populations, and declining ecosystems all at once.

Banning lionfish imports would hurt businesses, including aquariums and local restaurants in the long run. Due to lionfish’s unique features, they often draw crowds at aquariums. If a ban is placed on lionfish imports, the aquariums would no longer be able to have lionfish tanks to exhibit unless the fish are collected from Florida (Talbot, 2014). According to Moore (quoted in Talbot, 2014), this could hurt aquariums because banning all species of lionfish would send the message to all aquarium traders that “predatory marine fish are not welcome

here because the industry-hobby is not responsible.” Not only will banning imports hurt businesses, but some areas that have already put this policy in place have yet to see the desired results (Patoka et al., 2018, p. 3037). Patoka et al. (2018) assert the laws regulating animal trade like this “are often poorly communicated, poorly enforced.... Consequently, some laws may increase the number of unwanted introductions [to the environment] instead of decreasing them.” Additional sources present similar concerns with these bans as Kleitou et al. (2021) report the current policies are not effective enough to help control the lionfish populations. While banning lionfish imports can assist in stopping the invasion from worsening, this solution is most effective in mitigating the environmental effects during the initial stages of a foreign species invasion (Kleitou et al., 2021). Banning imports alone at this stage would not help control lionfish populations nor help the reef biodiversity recovery. While many believe banning lionfish imports will be a saving grace for Florida conservation efforts, there is evidence to support the argument it will do more harm than good.

Culling

The last major solution, which several governments along the Atlantic are already implementing, is culling. Culling is targeting and attempting to eradicate a specific species, typically due to its ecological effects. Culling mostly aims to completely eliminate a species from a certain habitat, but that is not always possible, as seen with lionfish in the Atlantic. This technique has been used in the past for many invasive species including the feral swine, Burmese python, and even domestic cats (Little, 2020). Previous studies done by Smith et al. (2017) and Guarnieri et al. (2020) on the smallmouth bass and the long-spined sea urchin, respectively, demonstrate culling effectively decreases the abundance of the targeted invasive species. Guarnieri et al. (2020) conducted a study on the long-spined sea urchin in which two testing areas and two control areas in the Mediterranean

just off the coast of Italy were monitored for long-spined sea urchin density over the course of three years. The sea urchins in the two testing sites were culled consistently during the three years. At the conclusion of the study, Guarnieri et al. (2020) reported a 75% decrease of sea urchin density as compared to the initial density, while the control sites had a reported increase in sea urchin density. Species richness and invertebrate densities reported no significant difference throughout the study; however, turf-forming algae and erect macroalgae significantly increased coverage in the two testing areas (Guarnieri et al., 2020). Invasive sea urchins are especially notable when discussing lionfish culling, as both species leave their invaded environments with significantly less species diversity. When sea urchins invade new areas, they overfeed and create barrens,

“benthic communities on rocky subtidal reefs that are dominated by urchins and coralline algae ... They are characterized by low primary productivity and low food-web complexity relative to kelp communities and are generally considered a collapsed state of the kelp ecosystem.” (Filbee-Dexter & Scheibling, 2014, p. 1)

Environments with uncontrolled sea urchin growth are comparable to environments where lionfish have invaded in the Atlantic; however, the negative ecological effects of these invasive marine species have been measured to decrease when the species has been properly culled (Smith et al., 2017).

A study on culling was done in the Caribbean by a group of scientists: Nicola Smith, Stephanie Green, and Isabelle Côté from Simon Fraser University in Canada; John L. Akins with REEF; and Skylar Miller from Cape Eleuthera Institute in the Bahamas. This study attempted to determine the effects of culling in varying intervals:

infrequent culling resulted in substantial reductions in lionfish density (60–79%, on average, albeit with large uncertainty) and slight increases in native prey species richness but was insufficient to stem the decline in native prey biomass. Cull-

ing every 3 months (i.e., quarterly) and every 6 months (i.e., biannually) had similar effects on lionfish density and native prey fishes because of high rates of lionfish colonization among reefs. (Smith et al., 2017)

On the other hand, over the past 20 years, multiple studies have been conducted that show “concentrated and maintained lionfish culls by divers restore native fish species relatively quickly” (Mills, 2020).

Properly managed culls are the current technique used by the Cayman Islands’ Department of Environment (DoE). In addition to this, local dive shops in the Cayman Islands began offering diving training that includes a lionfish culling certification in the program (Mills, 2020). After a diver gains this certification, they are legally allowed to cull lionfish from their own boats. The Cayman Islands’ DoE is trying to incentivize this option by spreading public awareness about how certified divers have the option to sell any lionfish they catch to local restaurants (Mills, 2020). Since many instances of proper culling can be seen of specifically marine species — for example, the long spined sea urchin discussed above — creating a plan and enforcing policies on lionfish culling can be made easier by basing the policies on preexisting ones that are proven effective. Florida can use and adjust a process that is already in place in the Caribbean.

Culling derbies are also a good way for governments and private organizations like REEF and the FWC to raise awareness for the negative effects of lionfish while providing a solution to the environmental issue. Culling derbies are events where people compete to catch the most lionfish out of those entered. Anyone with a culling license can enter these competitions. Culling derbies are a great way to help minimize the costs of culling. Organizations like REEF and the FWC sponsor “lionfish removal derbies and summer-long contests and has proclaimed open season on the pests with no daily bag limit or size limit” (Killer, 2020). Derbies reduce the costs of culling because

it limits the need for governments and private organizations to pay fishermen for culling services. In addition, individuals have the option to rent or use their own gear to participate in these events rather than organizations paying for fishing gear to supply the fishermen with.

More private organizations should choose to take advantage of the opportunities these derbies bring, as they provide economic incentives. The FWC holds derbies every year. Individuals can register to enter the event on the FWC website as commercial or recreational fishermen. These events have prizes correlating with the number of lionfish the individual catches and raffles are also often held at these events (Lionfish Challenge, n.d.). Divers entered in derbies can sell whole lionfish to restaurants and retailers for five dollars on average, but a fresh cut lionfish fillet can sell for around thirty dollars (Downey, 2017). One way to increase attendance at culling derbies is to offer culling certifications, as many local dive shops have begun to do in the Caribbean (Gallagher, 2013, p. 5). Hosting derbies and offering culling certifications allows organizations to charge rates for those interested in participating, and also gives the public an opportunity to get involved. For these reasons, citizens and organizations similar to the FWC and REEF need to aim their efforts more towards culling lionfish, as environmental and economic benefits can be seen.

While culling has been seen to effectively mitigate the negative effects of lionfish, many conditions must be met for culling to be effective and safe for the environment, which can be accounted for through policies and regulations. Other studies showed “that diver-led culling can be effective to control lionfish in priority areas; however, legislative framework changes would be needed [for this as well] to allow removal events though scuba diving” (Kleitou et al., 2021). A study on culling lionfish revealed even “reductions in lionfish abundance can stabilize or even reverse declines in native prey fish” (Côté et al., 2014, p. 4). Studies like this one conducted by Smith et al.

(2017) have proved culling is effective; the only factors causing its inefficacy are external, which can be aided by policy and regulations.

While culling is proven to be effective when done properly, it requires immense amounts of money and labor. Expensive gear must be used to cull as divers need scuba diving gear in addition to spears and nets. Culling may also have adverse effects on the environment. Reducing the lionfish population drastically in a short amount of time can have adverse effects on the native species to Florida reefs, as intraspecies competition will increase with little time to adjust (Smith et al., 2017). This means that since lionfish populations will decrease, prey populations will increase. If this is done in a short amount of time, the organisms consumed by prey populations will not have enough time to compensate for the increase in the prey population. This will lead the entire population to lack sufficient food availability, ultimately leading to famine for the prey and a further decline in the ecosystem.

Not only can adverse ecological effects occur with culling, but hurricanes have also proved to amplify the lionfish problem. The same study conducted by Smith et al. (2017) found the effects of hurricanes on culling success. The study found that after the hurricane, lionfish densities were greater on all culled reefs compared to non-culled reefs, and prey biomass declined by 92%, and species richness by 71%, on biannually culled reefs... stochastic events such as hurricanes can drastically limit the effectiveness of culling efforts. (Smith et al., 2017)

As Florida is an area with frequent hurricanes, the effects need to be considered when looking at the best solution for dealing with invasive lionfish. Events like hurricanes displace organisms throughout oceans. When lionfish are displaced and end up in culled areas, they often have little competition. This allows the lionfish to consume and reproduce with no limitations which ultimately leads to a significant decline in the native species populations.

Conclusion

When considering all the facts laid out throughout this paper, each option for reducing the lionfish population has positives and negatives when implemented. Training reef sharks is not a viable solution as research shows it is ineffective and dangerous for divers. Additionally, banning live lionfish imports can be effective in limiting the spread of invasive lionfish, but it does not help decrease the existing invasive lionfish. Culling is the most direct approach to decreasing lionfish populations. It has more research conducted on it than each of the other three solutions, often concluding that culling is safe for the environment and efficient, but other approaches can be implemented to incentivize culling for maximum effectiveness. Implementing policies to stop lionfish imports can be effective, but not to the extent that is needed to improve ecosystems. Increasing lionfish prevalence in the culinary market can be an effective incentive for culling as it provides more demand, so those with fishing licenses can collect fish to sell to restaurants for profit. As stated earlier, this offers citizens an economic benefit, as they have the options to sell their lionfish catches to local restaurants. Rachel Bowman, “a commercial spear fisherman in the Keys was one of the first people that actually started the commercial sale of spearing lionfish in the Keys, and she was actually quite successful getting that market started at Publix” (J. Grubich, personal communication, 4/27/2021). Supermarkets including this species in their seafood sections of the store would add to the demand, incentivizing fishermen to target lionfish.

Some papers made the argument that culling is one of the more time consuming and costly solutions of the four examined here. Traditional culling is time consuming because divers must spear individual fish rather than using a net to catch multiple at once. However, Steve Gittings, Science Coordinator for NOAA's National Marine Sanctuary Program, developed the Gittings trap, which is a trap designed to capture multiple lionfish and remove them from the area without harming them

in an effort to increase the efficiency of lionfish culling. After extensive testing, 68% of the traps deployed landed untangled on the seafloor and opened with no issue (Harris, 2020). The researchers additionally tested the traps' ability to withstand extreme weather conditions and found

the center of Tropical Storm Gordon passed ~150 km west of 12 deployed traps with maximum sustained winds of >110 km/h and recorded seas >5 m. Traps were retrieved two days later with all 12 found upright and no change in location, although traps were heavily fouled with algae. (Harris, 2020)

While the overall effectiveness of capturing and retaining lionfish was 44%, the fact that the trap can withstand extreme storms is important as it addresses the issue of lionfish densities increasing after hurricanes in invasive areas (Harris, 2020). Since the traps can withstand harsh conditions caused by hurricanes without moving or significant damage, these can be used to maintain ecosystems after stochastic events. The development of this trap is important for lionfish density management. The trap can significantly decrease the cost of culling outside of derbies because more fish can be caught with less manpower and equipment and the traps require little upkeep. Gittings is continuing to work on it to increase its effectiveness. Though this trap is not perfect, it is a step closer to significantly increasing the efficiency of culling and managing the invasive lionfish.

Each solution discussed in this paper has the potential to help manage invasive lionfish populations $\neg$ (with the exception of training reef sharks to hunt lionfish). Banning live imports of this species is necessary in order to stop the environmental issue from worsening by introducing more lionfish into the reefs. However, banning imports does not address controlling the invasive lionfish populations currently in the Atlantic or recouperating the destroyed environment. Increasing interest in lionfish in the culinary market can go hand in hand with culling. Increased interest in lionfish from restaurants and supermarkets increases demand. Fishermen would need to catch

more lionfish to meet the increased demand. Focusing efforts on culling is important for controlling lionfish populations. It is the most direct way to decrease the effect lionfish have on the environment at a rate that will not cause more negative effects on reefs. Culling derbies can help with the high costs of culling by having anyone with proper licensing enter with the incentive of prizes and the ability to sell the fish they catch to local restaurants and supermarkets. A combination of government policies and increasing the culinary market, with an emphasis on culling is the best course of action to return these declining ecosystems back to prosperity.

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