

The Invasion of Indo-Pacific Red Lionfish in Atlantic Coral Reefs

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The red lionfish (*Pterois volitans*) is a species native to the Indo-Pacific ocean basin but had spread rapidly throughout the sub-tropical Atlantic Ocean region by the early 2000s (Hixon et al. 2016). As is the case with many invaders, their effects on their new environment were initially unknown, but now, it has been heavily established that they have a clear, adverse effect on the fragile coral reef ecosystems they have entered. Lionfish thrive in their invasive range, allowing them to take over in a way unseen in their native ecosystem (Hixon et al. 2016). This leaves researchers searching for conservation and eradication possibilities before the lionfish can completely take over and begin pushing their invasive range boundaries even farther across the Atlantic coast (Chapman et al. 2016). Lionfish are successful invaders due to their advantage over naïve prey and once invaded, lionfish outcompete native predators and consume prey at a much greater rate. Complete eradication of the species is likely impossible in many places due to their heavy establishment, so efforts must shift to prevention, reduction, and conservation. Lionfish establish and flourish quickly throughout the Atlantic subtropics by means of their adaptive strengths in the region. Their ability to thrive is increased by means of being a generalist (Hixon et al. 2016) and by exploiting prey and predator naivety to the presence of a fish like the lionfish (Cure et al. 2012). Lionfish succeed in invading the Atlantic due to unique hunting techniques that allow them to grow quickly and by capitalizing on their ability to confuse prey and predators with their appearance.

Though they display the same hunting patterns in their invasive range as in their native one, lionfish catch more, larger prey in the Atlantic, which results in them being larger as well (Cure et al. 2012, Pusack et al. 2016). Cure et al. (2012) looked at differential hunting behaviors in the lionfish's native and invasive range, focusing on the islands of the Philippines, Guam, the Bahamas and Caymans. Irrespective of range, lionfish were highly crepuscular hunters, catching most of their prey in the dawn and dusk hours and also had similar kill rates (Cure et al. 2012). However, the average size of the lionfish's prey was nearly twice as large as the prey in their invasive region. Furthermore, they also consumed a greater variety of prey species in the Atlantic than the Pacific (Cure et al. 2012). Though they are not consuming significantly more fish than they would in their native range, the Atlantic-invading lionfish are consuming more prey biomass, an adaptation to their new range that allows them to grow larger.

Pusack et al. (2016) looked at lionfish surrounding the same native and invaded islands as Cure et al. (2012) and found that the lionfish in the Atlantic had greater growth rates and attained larger sizes than their native counterparts. They found lionfish growing nearly twice as fast on average in the Atlantic than the Pacific and modeling based on this study predicted overall larger lionfish in the invaded region (Pusack et al. 2016). Faster growth of lionfish populations only perpetuate and compound the issue found by Cure et al. (2012) of consuming larger prey and if it continues throughout the established invasive populations, it could mean greater extirpation of native species. These eating habits are not only detrimental, but because the lionfish are generalists in their predation, they take advantage of prey unfamiliar with piscivores like them (Pusack et al. 2016).

The lionfish is an exceptional predator within the invaded coral reefs due to the lack of experience of native fish to species like them (Hixon et al. 2016). Since many native fish are unfamiliar with this type of predation, lionfish eliminate many of them, including juvenile predatory fish, further increasing access to other prey (Hixon et al. 2016). They also have advantage over inexperienced predators; lionfish have many defenses from potential predators, most obviously their venomous spines (Albins & Lyons 2012). However, they also have an advantage with their specific coloration and stripes, which benefits them by both deterring predators and confusing or distracting prey (Hixon et al. 2016). Indicative of their control at the top of the food chain in these invaded waters, they are rarely attacked by predators; one study documented no attacks on

lionfish throughout a three-year period (Cure et al 2012). These physiological advantages take away much of the biotic resistance that could otherwise threaten lionfish, leaving prey greatly susceptible to attack. One major advantage lionfish have in hunting prey is their ability to "shoot" jets of water at prey, disorienting them (Albins & Lyons 2012). However, there are more documented incidences of lionfish using the jet-blowing technique in their native range (Albins & Lyons 2012, Cure et al. 2012) which may imply that the native Atlantic fish are naïve enough to the predation of the lionfish that the ambush technique suffices. Naivety of prey can explain why lionfish are able to capture larger prey than in their native range; in their home range, only the weak and small prey get caught by lionfish, but in the Atlantic, prey species do not recognize the threat of lionfish (Cure et al. 2012). The lack of experience native fish species have with the lionfish as predators causes great gaps in biotic resistance that allows lionfish to target all varieties of prey, putting immense stress on species that play crucial roles in their native coral reefs.

Lionfish pose an incredible threat to the ecosystem they have entered on account that they appear to do better as invaders rather than natives in the Indo-Pacific. A general lack of biotic resistance allows them to rise up the food chain; there is even evidence that their skin possesses antibacterial qualities, granting them immunity from bacteria that otherwise sicken and affect native fish (Hixon et al. 2016). On top of that, there is little recorded evidence of parasites interacting with lionfish, suggesting that there are lower levels of occurrence with invasive lionfish than with the native coral reef fish, another advantage in their invaded region (Morris et al. 2009). Less understood is the advantages gained by lionfish from abiotic factors; though Cure et al. (2012) spoke briefly on light levels at crepuscular times differing in native and invasive ranges slightly and Pusack et al. (2016) discuss factors such as varying water temperature and depth, few studies are dedicated solely to the relation between abiotic factors and increased benefits for invasive lionfish. Further understanding of the role of abiotic factors benefitting lionfish can help increase understanding of how lionfish have become such successful invaders in the Atlantic.

As a critically endangered ecosystem, the rapid establishment and proliferation of lionfish throughout the Atlantic coral reefs threatens many already at risk endemic species (Rocha et al. 2015). As a generalist piscivore well protected by their venomous spines, lionfish have the capacity to inflict great damage on local fish populations without much threat to their own survival. Invasive lionfish disrupt the natural cycle of coral reef systems by competing with native predators and consuming large amounts of prey, leading to reduced recruitment and possible extirpation of native fish species.

The main problem with introducing a novel predator, such as the invading lionfish, into an ecosystem is that it disrupts the long-established regulatory processes of predator-prey in that area. Density-dependent mortality is one of the major cyclical relationships established in the Atlantic coral reef populations between prey and predator with populations increasing when numbers are low and decreasing when they are large (Ingeman 2016). While native predators, like groupers, are contained within this pattern, the introduction of lionfish disturbs the cycle of density dependence by competing with native predators (Ingeman 2016). The problem with lionfish competition arises in the fact that they do not fill the same ecological niche as the native predators since they vary their hunting methods and are much more voracious eaters, consuming more fish than similarly-sized natives would (Albins 2013). In his study, Albins (2013) demonstrated that lionfish also cause a significant reduction in species richness that is not reflected in the habits of a similar native predator, the coney grouper. The lionfish competes for prey with the grouper but does not fill in the same ecological role as the native, therefore causing damage to the prey population not reflected in the native's predation habits. By competing with – and in many ways outcompeting – native predators, lionfish pose a great threat to vulnerable and already endangered prey species.

Many species of coral reef fish are already threatened and the presence of piscivorous invaders like the lionfish greatly reduces their recruitment and survival through intense predation. Species like the social wrasse can often escape predation when they become larger adults. However, lionfish will eat these adults as well, posing a greater threat; the social wrasse is already one of five fish listed at the highest risk of extinction (Rocha et al. 2015). Not only are lionfish eating more adult prey species, but their rate of consumption is also high; one study noted a

single lionfish consuming more than twenty fish in a single, thirty minute feeding session (Rocha et al. 2015). A rate like this could prove detrimental to a small population in a reef community, leading to local extirpation. The fairy basslet, another fish similar to the social wrasse and equally as targeted by lionfish, faces similar risks due to the new invaders (Rocha et al. 2015). One experiment by Ingeman (2016) found that on native only reefs, fairy basslet populations remained stable over a twenty eight day period, but two out of fourteen populations went locally extinct on reefs with lionfish present. Even species that are not driven to extinction face serious reductions in recruitment due to lionfish presence that may affect their populations in the long run (Albins & Hixon 2008). In one study, up to sixty percent of native species faced low levels of recruitment on lionfish populated reefs (Albins & Hixon 2008). The lionfish's success as a predator in their invasive range and the fragility of the ecosystem they enter is the reason why they must be controlled or their negative effects on recruitment and mortality will only continue to compound the threats Atlantic coral reefs already face.

Though many other theories have been posited to explain the rapidly diminishing abundance and richness of coral reef species in the Atlantic, the invasion of lionfish proves to be one of the dominating threats. For instance, Green et al. (2012) showed the unlikelihood of factors like widespread recruitment failure, disease, or increased native predation to be affecting these smaller prey species' populations. Along with that, native predators are part of a cycle of population control for species and only the disruption of that cycle, such as the introduction of lionfish, can have such a great impact on species decline (Ingeman 2016). These factors all contribute to the fact that mitigation is necessary for lionfish populations in coral reefs or else severe harm to the native species and ecosystem will continue.

Lionfish have become well established across the Atlantic due to their widespread numbers and clear establishment success; it is unlikely that complete eradication will ever be possible (Chapman et al. 2016). However, much can be done to help mitigate their effects and restore native coral reef species. The removal of lionfish to ease stress on Atlantic ecosystems is an effort that requires consistent maintenance in order to prevent population numbers from increasing during lag times (Albins & Hixon 2008). Consistent culling combined with the use as a potential food and income source for local communities appear to be the most economically sound and long lasting opportunities for mitigation and decline in invasive lionfish population.

The process of culling lionfish is an important key to their management in the invaded region; however, infrequent partial culling is likely the most effective method as opposed to sustained complete culling attempts. The process of culling invasive species like the lionfish, though highly beneficial when properly executed, comes with the negative repercussion of changed invader behavior (Cote et al. 2014). Lionfish on reefs that were routinely culled, as opposed to un-culled reefs, were more often hidden or active only at deep levels during the day in response to hunting; they were also quicker to respond to and evade divers (Cote et al. 2014). Considering that lionfish are already inclined to be crepuscular (Cure et al. 2012), this behavior may force them to increase hunting at dawn and dusk, further stressing the prey populations.

However, culling should not be abandoned entirely as it still is effective in decreasing lionfish population at a regional level; rather, culling efforts should be irregular in order to prevent behavioral adaptations (Cote et al. 2014). This would also require less total time as complete culling, making it a more economically sustainable practice (Cote et al. 2014). These methods would allow native fish populations the opportunity to slow the rate of decline or even stabilize. These efforts need not be carried out solely at a government level, but can be effectively participated in by members of effected communities.

The inclusion of the local community in invaded areas can greatly reduce lionfish numbers by increasing interest in conservation efforts and promoting their use as a food source. With seafood being a major component of many afflicted Atlantic coastal communities, the effects of lionfish on native fish populations can be detrimental environmentally and economically (Chapman et al. 2016). Members of fishing communities with knowledge of lionfish invasion and its effects are more motivated to take action; one study reported the majority of respondents were willing to eat lionfish (Chapman et al. 2016). Awareness of lionfish as invasive can help create a market for it as seafood. Since it would be benefitting local economy, citizens may be more willing to pay for it. Lionfish is

also a good candidate for human consumption for its fillet percent yield and beneficial nutrients (Morris et al. 2011). The fillet yield of lionfish on average is about thirty percent, on par with other popular commercial fish like grouper, but are more nutrient rich with higher levels of n-3 fatty acids (Morris et al. 2011). The benefit to the ecosystem will likely pique interest in both local and tourist consumption as well as facilitate economic growth in fishing communities (Chapman et al. 2016). By creating demand in the name of conserving reefs and benefitting local fisheries, participation of locals in reducing lionfish populations can be sustained. However, the seafood industry is not the only way to get the community involved in lionfish reduction efforts.

The creation of events like lionfish 'derbies' generates another economic opportunity for local communities via lionfish removal. Derbies provide an opportunity for local recreational divers to compete in capturing the most lionfish, often for a prize (Chapman et al. 2016). These derbies have resulted in the removal of thousands of lionfish over several years with immediate local reduction of up to sixty percent (Green et al. 2013). These derbies could further amplify the efforts put forth by helping to reduce lionfish numbers in areas where commercial fishing is prohibited (Chapman et al. 2016); the precision of capturing the lionfish with a hand net or spear, as employed by divers, negates the possibility of bycatch that commercial fishing risks, further protecting the native fish species. By specifically targeting high-risk areas, derbies can make the most effective use of a single day tournament to reduce as great a quantity of lionfish as possible (Green et al. 2013). Events like derbies have the double benefit of reducing lionfish populations and engaging the community, which can only continue to raise awareness for mitigation efforts of the invasive species.

Lionfish establishment has occurred with such rapidity throughout the Atlantic subtropics that it is unlikely the ocean basin will ever be entirely eradicated of the species (Albins & Hixon 2008). However, regional mitigation and extirpation with focus on high-priority areas of the species is possible, bringing the possibility of a slower decline rate and stabilization of native coral reef fish (Green et al. 2012). Looking towards the future, the prediction of lionfish spread and proactive prevention measures will be important for keeping lionfish from spreading and establishing into at risk areas. Coral reefs are already endangered ecosystems, facing threats from human actions such as coastal development and disasters like oil spills (Rocha et al. 2015). The protection of these habitats and the endemic species they contain is essential for helping maintain marine biodiversity.

Note: Eukaryon is published by students at Lake Forest College, who are solely responsible for its content. The views expressed in Eukaryon do not necessarily reflect those of the College.

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