Commentary

Setting the record straight on invasive lionfish control: Culling works

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Abstract

Indo-Pacific lionfish have invaded large parts of the western Atlantic, Caribbean and Gulf of Mexico, and have already caused measurable declines in native Atlantic reef fauna. Culling efforts are occurring across the region, particularly on coral reefs, to reduce local lionfish abundances. Frequent culling has recently been shown to cause a shift towards more wary and reclusive behaviour by lionfish, which has prompted calls for halting culls. However, the effectiveness of culling per se is not in question. Culling successfully lowers lionfish numbers and has been shown to stabilise or even reverse declines in native prey fish. In fact, partial culling is often as effective as complete local eradication, yet requires significantly less time and effort. Abandoning culling altogether would therefore be seriously misguided and a hindrance to

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conservation. We offer suggestions for how to design removal programs that minimize behavioural changes and maximize culling success.

The invasion by Indo-Pacific lionfish (*Pterois volitans* and *P. miles*) of marine habitats throughout large parts of the western Atlantic, Caribbean and Gulf of Mexico, is arguably the best documented and among the most damaging of all marine invasions. Lionfish were first reported off the coast of Florida in 1985 (Schofield, 2009), and the most likely vector of introduction was the deliberate release of lionfish by aquarists (Semmens et al., 2004; Whitfield et al., 2002). In the following two decades, reports slowly increased in frequency and geographic range and by 2004, lionfish off North Carolina had become as abundant as the most common native grouper species (Whitfield et al., 2007). The same year, lionfish were first seen on Bahamian coral reefs (Schofield, 2009), at which point the invasion front rapidly proceeded eastward and then southward. Lionfish are now established around every island, along most of the Central and South American coasts of the Caribbean Sea, as well as most of the Gulf of Mexico (Côté, Green & Hixon, 2013). They are found in most marine habitats – temperate hard-bottom reefs (Whitfield et al., 2002, 2007), shallow and mesophotic coral reefs (Albins & Hixon, 2011; Biggs & Olden, 2011; Lesser & Slattery, 2011), seagrass beds (Claydon, Calosso & Traiger, 2012), mangroves (Barbour et al., 2010), and 6.5 km from the ocean in nearly fresh water estuarine rivers (Jud et al., 2011). They range in depth from less than 1 m to more than 300 m.

Predatory lionfish have already had measurable impacts on native Atlantic fauna. Green et al. (2012a) observed a 65% decline, on average, in prey fish biomass over just 2 years on heavily invaded natural reefs in The Bahamas. On small experimental reefs, the effects are even greater. A single lionfish can reduce the recruitment of small native fish by more than 90% in a matter of weeks, exceeding the mortality imposed by a comparable native fish predator (Albins & Hixon, 2008; Albins, 2013). The impacts on invertebrates are more difficult to assess, but they are expected to be great since invertebrates can contribute a substantial portion of lionfish diets (Morris & Akins, 2009).

It is clear that eradicating lionfish from the Atlantic Ocean is not possible with current tools and technologies. Simulation models suggest that substantial reductions in lionfish abundance might be achievable *at a regional scale* with frequent removal of lionfish, but removal rates have to be high (e.g., 27–65% of the population each year) and cessation of removals is expected to lead to quick lionfish recovery (Arias-González et al., 2011; Barbour et al., 2011; Morris, Shertzer & Rice, 2010). This level of effort is unlikely to be achieved at a basin-wide scale. However, it is possible on local scales, through culling (by spearfishing and hand-netting) by concerned divers and through organised lionfish derbies and tournaments (Akins, 2012).

Interestingly, regular culling can affect lionfish behaviour. On Bahamian patch reefs that were experimentally culled for 2 years to mimic control efforts, resident lionfish were less active and hid more deeply within the reef during the day, when culling took place. These fish also reacted at a greater distance from approaching divers than lionfish on patches that were never culled (Côté et al. 2014). Such effects are not unexpected since similar shifts have been noted in hunted birds and mammals (e.g., Caro, 1999, Casas et al., 2009, Brooke, Johnson & Ritchie, 2012). Behavioural shifts might be a learned response, if lionfish that survive culling come to associate daytime and/or divers with a stressful event and change their behaviour accordingly.

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Alternatively, culling could select for shy individuals, if bold lionfish (i.e., the ones that are active by day and hang out well above the reef) are preferentially located and killed.

Although it appears that culling can make lionfish more reclusive (Côté et al., 2014), **the effectiveness of culling per se is not in question**. For example, on coral reefs around Little Cayman, targeted lionfish removals occurring irregularly over 7 months reduced the overall abundance and the mean size of lionfish (Frazer et al., 2012). More importantly, **reductions in lionfish abundance can stabilise or even reverse declines in native prey fish**. This was demonstrated by Green et al. (2014) in a large-scale field experiment in which lionfish were culled, partially or fully, from some reef patches but not others. Lionfish abundance could be maintained at targeted densities with relatively infrequent removals, and partial culling halted the erosion of native fish biomass as effectively as full culling. The latter finding was particularly important because partial culling required 30% less time and effort to achieve than the complete removal of lionfish.

The extent to which current culling practices are shifting lionfish behaviour across the region, and whether such shifts will actually reduce the effectiveness and/or efficiency of culling activities, remain unknown. However, in light of these potential effects, we urge cullers to adopt removal practices that (1) minimize the extent to which removals selectively target 'bold' lionfish, and (2) maximize the success of initial capture attempts. These goals require training in the use of appropriate capture tools and techniques (e.g., through short training seminars; www.reef.org/lionfish), and careful planning of removal events. For example, conducting detailed surveys of the habitat to detect cryptic (or 'shy') individuals (such as the methods outlined in Green et al., 2013) or scheduling removals during low-light/crepuscular times of peak activity when even wary fish are more likely to be out in the open may increase access to all

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individuals and result in higher capture success. For lionfish that survive culling attempts, any negative association with divers should attenuate over time, depending on lionfish memory span and the frequency of culling.

Culling is currently the best method available to control lionfish numbers, and we have solid evidence that when lionfish populations are kept under check, native fish can recover. Any potential effects of shifting behaviour of culling success should be readily overcome by improving the training of divers, modifying the frequency of culling and targeting shy lionfish. Calls to abandon culling altogether because they can cause shifts in lionfish behaviour (e.g., Levitan, 2014; Soniak, 2014) are therefore seriously misguided.

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