Assessment and Management of Invasive Lionfish Populations in Bermuda

Evaluación y Manejo de Poblaciones Invasoras de Pez león en las Bermudas

Évaluation et Gestion des Populations Envahissantes de Poisson-lion aux Bermudes

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EXTENDED ABSTRACT

In 2000, Bermuda was the first western Atlantic location outside of United States waters to detect the presence of Indo-Pacific lionfish (*Pterois volitans* and *P. miles*). The ecological impact and invasive character of these introduced species has since been demonstrated by numerous researchers in varied locations, as reviewed by Arndt et al. (2018). The lionfish population in Bermuda has expanded at a slower rate than populations elsewhere in the region, however, and the abundance of lionfish in shallow reef zones initially remained relatively low (Eddy et al. 2013, Eddy 2016).

A scheme to promote culling of lionfish officially began in 2008, with special permits issued by the Bermuda Government Department of Environment and Natural Resources, and the first culling tournament – Groundswell – was held in the summer of 2011. Cullers have since reported increasing numbers of lionfish at shallow depths over time. There are now quarterly tournaments that take various forms, ranging from 1 day in the summer, a weekend in the spring, a long weekend in the fall, and the entire month of January, which allows for more culling opportunities at times when the weather is less predictable.

In 2009, early technical dive expeditions in Bermuda stumbled upon dense populations of lionfish at a few select mesophotic sites at 60 m depth. These sites were revisited on multiple occasions and consistently yielded high catches of lionfish, leading to the presumption that they represented "hotspots" of lionfish abundance. Quantitative surveys to assess lionfish and prey fish densities began in 2013 with the support of a Darwin Plus grant (DPLUS064) from the UK's Department of Environment, Food and Rural Affairs (DEFRA). Divers utilizing SCUBA, nitrox and technical trimix assessed lionfish densities in 25 m x 10 m quadrats (Green 2012), across 5 depth zones (10 m, 20 m, 30 m, 45 m, and 60 m) at 14 sites spread around the Bermuda platform. Potential prey fish in the same area were also surveyed using 2 m x 30 m belt transects (Green et al. 2012).

These surveys revealed low densities of lionfish on shallow reefs (10 m, 20 m, and 30 m sites) across the Bermuda platform but, in contrast, found greater densities of lionfish on mesophotic reefs (45 m and 60 m sites), where an average density of 297 fish/ha was reported from sites at 60 m depth (Figure 1). Concurrently, assessment of lionfish distributions and fish community composition were conducted using Baited Remote Underwater Video (BRUVs) at additional sites around the Bermuda platform to depths of up to 90 m. These surveys detected lionfish at low to moderate densities, but did not discover any dense aggregations in areas other than the known "hotspots" at 60 m.

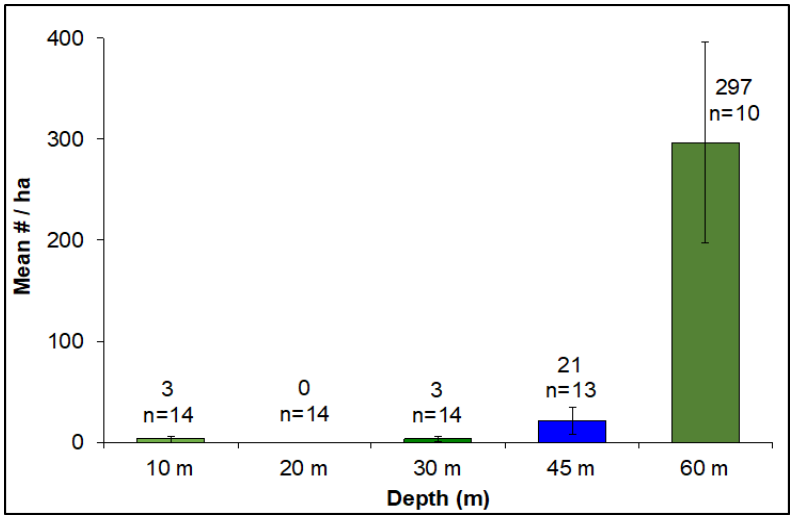

Figure 1. Mean number of lionfish per hectare across a depth gradient during initial monitoring efforts (2013 – 2015).

Lionfish densities across mesophotic sites at 60 m depth were found to differ significantly, with observations ranging from 0 fish/ha at some sites to 1100 fish/ha at others (Figure 2). Inter-site comparisons of possible ecological drivers of variable lionfish densities on mesophotic reefs revealed a strong interactive effect of seawater temperature and prey fish biomass. These data indicate that cold-water upwelling currents may be fueling the food chain, leading to high biomass of prey fish at specific sites, which subsequently results in increased lionfish densities. Thus, while temperature is the overall driver, it is the availability of prey that dictates lionfish distribution at mesophotic sites in Bermuda (Goodbody-Gringley et al. *In preparation*).

Managing lionfish at mesophotic depths presents unique challenges as these areas are beyond recreational diving limits. To overcome these challenges, we have incorporated technical diving, baited remote underwater video (BRUVs), and environmental DNA (eDNA) to monitor populations, and inform targeted removals. From August 2017 through January 2018, three mesophotic "hot spots" were monitored and culled on a monthly basis. At each site, surveys were conducted of lionfish densities and prey fish densities, and all lionfish were removed from the sites. There was a reduction in lionfish density at all three sites over time. However, there was also a corresponding decline in prey fish abundances over time. Thus, it remains unclear whether the reduction in lionfish was due to the impact of continued culling or to seasonal shifts in prey availability.

The lobster trap fishery in Bermuda has continually reported significant bycatch of lionfish from the "offshore" fishing area that encompasses the 60 m depth band where lionfish occur in large numbers. Bermuda's Fisheries Regulations do not allow 'fish pots', so, between 2014 and 2016, we worked with fishers to modify local lobster traps to target lionfish (Pitt and Trott 2014). After several iterations, traps with wire funnels terminating in a black 7" ring and traps with two top-loading plastic funnels produced the best trade-off between lionfish catch and bycatch (Pitt and Trott 2014 and 2015). Modified versions of the clam-shell like trap developed by NOAA (Gittings 2017) are also currently being tested at mesophotic sites. Initial deployments have caught 2 lionfish, whilst up to 5 individuals were observed aggregated around traps via the attached cameras.

We are also working in cooperation with Robots in Service of the Environment (RSE) and Atlantic Lionshare Ltd. to develop remotely operated lionfish culling devices. The present RSE prototype, still in development, uses an electrical current between two paddles to stun lionfish and a suction device to draw the fish into a containment unit. In contrast, Atlantic Lionshare is developing an ROV that utilizes retractable spear technology.

Despite these activities, we are still in the early stages of our control efforts and remain reliant on volunteer cullers in the shallows and on grant funding from various agencies to support our deep-water removals. Thus, a key objective is to promote a lionfish fishery in Bermuda, with the goal of increasing public demand to drive the market

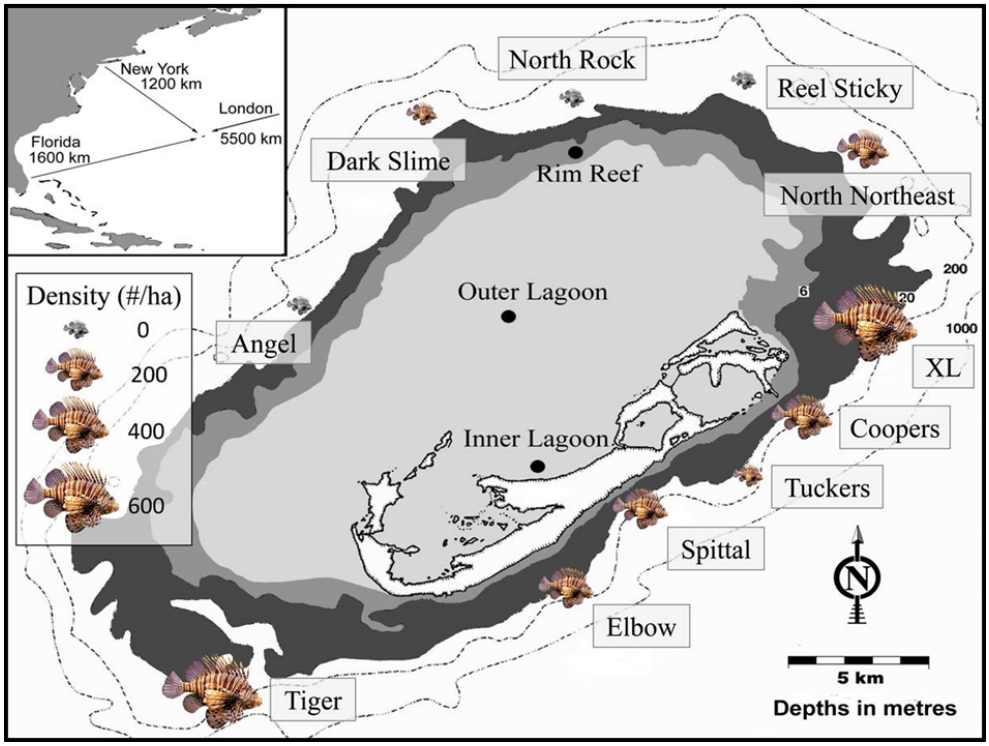

Figure 2. Map of *in situ* survey sites of mesophotic reefs (60m depth), where lionfish densities were recorded. The size of the fish corresponds to lionfish density, indicating significant differences among sites.

and encourage local fisherman to target lionfish as a high-end product. Therefore, in addition to the trapping partnerships with commercial fishers, several local cullers have been granted special permits to sell lionfish caught during research and control efforts, and relationships have been established with several restaurants and grocery stores to whom lionfish are provided on a regular basis.

Having approached lionfish management from a variety of angles, it is clear that ongoing control will require a broad spectrum of management tools along with consistent monitoring of populations to evaluate their effectiveness. Importantly, the Bermuda Lionfish Task Force has helped to bring different stakeholder groups together in order to co-ordinate the various lionfish research, monitoring and control efforts, and to combine these with public outreach work.

KEYWORDS: Invasive lionfish, lionfish control, mesophotic, Bermuda

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LITERATURE CITED

Arndt, E., M.P. Marchetti, and P.J. Schembri. 2018. Ecological impact of alien marine fishes: insights from freshwater systems based on a comparative review. *Hydrobiologia* **817**:457-474.

Eddy, C., J. Pitt, S.R. Smith, G. Goodbody-Gringley, J. Gleason, and D. Bernal. 2013. Preliminary Analysis of Lionfish (*Pterois volitans* and *P. miles*) Populations in Bermuda. *Proceedings of the Gulf and Caribbean Fisheries Institute* **66**:186-187.

Eddy, W.C. 2016. The Ecological Impact of Invasive Lionfish (*Pterois volitans* and *P. miles*) on Bermuda's Marine Environment. Doctoral thesis. University of Massachusetts at Dartmouth, MA, U.S.A.

Gittings, S.R. 2017. Encouraging results in tests of new lionfish trap design. *Proceedings of the Gulf and Caribbean Fisheries Institute* **69**:149-156

Goodbody-Gringley, G., W.C. Eddy, J.M. Pitt, A.D. Chequer, and S.R. Smith. [In prep.] Ecological drivers of invasive lionfish (*Pterois volitans* and *P. miles*) densities on mesophotic reefs. Manuscript submitted for publication.

Green, S.J. 2012. Monitoring: An Essential Action. Pages 51-71 in: J.A. Morris Jr. (Ed.) *Invasive Lionfish: A Guide to Control and Management.* Gulf and Caribbean Fisheries Institute Special Publication Series, No. 1. Marathon, Florida. 113 pp.

Green, S.J., and J.L. Akins, A. Maljković and I.M. Côté. 2012. Invasive lionfish drive Atlantic coral reef fish declines. *PLoS ONE* **7**(3): e32596.

Pitt, J.M. and T.M. Trott. 2014. Trapping Lionfish in Bermuda, part II: Lessons learned to date. *Proceedings of the Gulf and Caribbean Fisheries Institute* **68**:221-224

Pitt, J.M. and T.M Trott. 2015. A lionfish trap for use in Bermuda, with potential applications elsewhere. Poster and workshop presentations at the *68th Gulf and Caribbean Fisheries Institute*, Panama City, Panama. http://www.car-spaw-rac.org/IMG/pdf/12-abstract_joanna_pitt.pdf