Invasive lionfish drive fish community shifts across the western Atlantic

El pez león invasor impulsa los cambios de la comunidad de peces en el Atlántico occidental

Les poissons-lions envahissants entraînent des changements dans les communautés de poissons dans l'Atlantique Ouest

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EXTENDED ABSTRACT

INTRODUCTION

Lionfish (*Pterois volitans* and *P. miles*) have become invasive throughout the tropical western Atlantic (Schofield, 2010) and have caused declines in reef fish abundance (Ballew et al., 2016), species richness (Albins, 2015) and recruitment (Albins and Hixon, 2008). Despite the widespread distribution of invasive lionfish in the western Atlantic, their impacts are mostly estimated from small-scale patch reef studies over short timescales of weeks to months. However, it has been suggested that patch reefs are highly unrepresentative of most reefs within the western Atlantic (Hackerott et al., 2017).

In this study we investigate the ecological effects of invasive lionfish on native fish communities across the western Atlantic using data centred on year of lionfish arrival in each location, whilst also controlling for a comprehensive set of contextual variables.

METHODS

We obtained data on native fish communities from the Atlantic and Gulf Rapid Reef Assessment (AGRRA) database (Marks, 2018), which contains belt transect data from coral reefs across the western Atlantic. The AGRRA data is labelled by country, sub-region, site and transect. We only selected sub-regions with data from at least one pre-invasion and one post-invasion year, with a minimum of two sites per sub-region per year. Pre- and post-invasion years were defined based on the year of lionfish arrival in each sub-region, obtained from the USGS Non-indigenous aquatic species database (USGS, 2020). Our final dataset includes 11,753 transects, 584 sites, 21 sub-regions and eight countries, covering multiple reef types and spanning a maximum of ten years pre-invasion and eight years post-invasion.

Point impact events such as bleaching and hurricanes may impact native fish communities and if not accounted for correctly, their impacts could be wrongly interpreted as being driven by lionfish. To reduce the potential influence of these events, we (i) used temporal data offsetting, whereby data for each sub-region were centred on year of lionfish arrival and lionfish impacts were analysed in relation to years since invasion and (ii) controlled for a range of contextual variables including biophysical, social and management variables.

We investigated the effects of the lionfish invasion on abundance, biomass, species richness, species diversity (using the Shannon-Weaver diversity index (Shannon and Weaver, 1949)) and species presence/absence for the whole fish community. We also investigated the abundance of 6-10 cm Scaridae (parrotfish), Pomacentridae (damselfish) and Haemulidae (grunts), all of which are found in lionfish diets (Peake et al, 2018).

Our analysis used non-metric multidimensional scaling (nMDS) and similarity percentages (SIMPER) analysis to assess changes in native fish community composition and Generalised Additive Mixed Models (GAMM) to assess changes in fish community metrics over time. GAMMs were used as they can model non-linear trends over time without *a-priori* hypotheses about the shapes of the trends.

RESULTS

For the multivariate analyses, the data were split into five categories: pre-invasion and 0-1, 2-3, 4-5 and 6-7 years post-invasion. We found a significant difference between year categories for all response variables (p=0.001 for all). For all variables except biomass, the pre-invasion community was distinct from all communities sampled two or more years post-invasion. The Scaridae (parrotfish), Labridae (wrasse), Pomacentridae (damselfish) and Haemulidae (grunts) families contributed the most to the dissimilarity between the invasion year categories.

Years since lionfish invasion was a significant predictor for all response variables (p<0.05 for all). All the whole fish community metrics (abundance, biomass, richness and diversity) show an increase that began prior to lionfish invasion, with richness, diversity and abundance showing declines that begin approximately five years after lionfish invasion and continue until the end of the study. Like the whole fish community metrics, parrotfish and damselfish abundance increased at the beginning of the lionfish invasion, but both showed changes at approximately five years since lionfish invasion, with parrotfish abundance beginning to decrease and damselfish abundance reaching a plateau. In contrast, grunt abundance increased prior to lionfish invasion and decreased from approximately one year after lionfish invasion until the end of the study.

DISCUSSION

The observed difference in fish communities between pre-invasion and two or more years post-invasion indicates that lionfish invasion results in permanent and stable post-invasion fish communities, as has been observed in a study from Belize (Hackerott et al., 2017). The most influential families driving these differences are all found in lionfish diets. This suggests that the consumptive effects of lionfish are more pronounced than the non-consumptive effects, which could impact both prey and non-prey species and can include reductions in feeding (Eaton et al., 2016, Kindinger and Albins, 2017), competition for shelter use (Hunt et al., 2020, Trehern et al., 2020) and reductions in fecundity (Davis, 2018).

Our GAMMs showed a continuation of pre-invasion trends during the initial years of the lionfish invasion. The positive trends we observed were unexpected, as most studies indicate a negative effect of lionfish on prey fish abundance and richness (Albins, 2015; Ellis and Faletti, 2016), with a few studies indicating no effect (Hackerott et al., 2017). However, native fish abundance and biomass can continue to increase in the presence of lionfish provided that lionfish density is below a reef specific threshold (Green et al., 2014). Therefore we suggest that lionfish density was too low to impact native fish communities in the initial stages of the lionfish invasion.

We observed a region-wide negative impact of lionfish at approximately five years post-invasion. The synchronicity of declines across different families and metrics suggests a single driving force that acts approximately five years after lionfish invade an area. These synchronised declines are not the result of a single region-wide event (e.g an extreme climatic event) because our data are temporally staggered, with lionfish invasion dates ranging from 2007-2012. Instead, we suggest that the changes observed are caused by lionfish reaching a density at which their negative impacts on native fish communities become detectable at a regional scale.

KEYWORDS: Lionfish, invasive species, regional impacts, fish communities

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