Lionfish Sources and Sinks in the Atlantic: Are Reef Fisheries in the Gulf of Mexico at Risk?

Fuentes y Sumideros del Pez León en el Atlántico: Son Pesca en los Arrecifes en el Golfo de México en Situación de Riesgo?

Sources Lionfish et les Puits dans l'Atlantique: Sont Pêche dans les Récifs dans le Golfe du Mexique à Risque?

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EXTENDED ABSTRACT

Introduction

Invasive lionfish (*Pterois volitans/miles*) spread swiftly after their introduction to South Florida in the 1980s and now inhabit diverse habitats throughout the entire Caribbean Sea, tropical western Atlantic, and Gulf of Mexico (GOM). Lionfish are generalist consumers that feed voraciously, reducing prey abundance and richness with likely strong ecological consequences (Albins and Hixon 2008, Green et al. 2012, Côté et al. 2013). Gut content analyses show that lionfish feed on commercially and recreationally important fisheries species such as lutjanids and serranids – i.e., snappers and groupers – perhaps imposing economic damages to these fisheries (Morris and Akins 2009, Valdez-Moreno et al. 2012). Lionfish densities have been empirically, but only sparsely, measured in their invaded range. Lacking is a comprehensive assessment of lionfish sources and sinks and potential lionfish abundance throughout their non-native range. Such data are important to forewarn of possible lionfish impacts to sympatric, commercially valuable fishes, such as snappers and groupers, and also to help direct lionfish removals. Our aims for this study were twofold:

i) To forecast lionfish larval source and sink locations throughout their invaded range using a biophysical computer model, delineated by low to high density 'zones', and
ii) To assess the vulnerability of five recreationally and commercially important snapper and grouper species – *Epinephelus morio, Mycteroperca microlepis, Epinephelus flavolimbatus, Lutjanus campechanus*, and *Rhomboplites aurorubens* – to lionfish predation and competitive pressure with respect to sympatric distributions to lionfish larval sinks (i.e., assuming more larval recruitment produces more adult lionfish) in the GOM.

METHODOLOGIES

The biophysical model we used was previously applied to study the recruitment and connectivity patterns of lionfish (e.g., see Johnston and Purkis 2014a, 2014b, 2015), invasive grouper and snapper in Hawai'i (Johnston and Purkis 2016), and the regal damselfish in the GOM (Johnston and Akins 2016). The adaptation of the model used in this study implements a Lagrangian diffusion algorithm that coupled ocean conditions with lionfish life strategies to forecast lionfish dispersal, recruitment, and resultant lionfish abundance.

First, simulations using the model were run spanning three years, a length of time reasonably sufficient to demonstrate lionfish abundance in sink locations over multiple lionfish generations. Throughout the lionfish's invaded range, locations were selected every 1/10° (~11 km) - in water depths of 300 m or less (i.e., the theorized depth limit of lionfish) - to serve as "founder locations" of breeding lionfish, totaling 13,024 evenly-spaced geographic points. Contemporary lionfish abundance was not considered in the analysis to provide a density-independent evaluation of potential abundance throughout their invaded range based exclusively on ocean conditions and life history strategies of lionfish. Model outputs consisted of geo-tagged sources (i.e., locations of prolific spawning) and sinks (i.e., locations of dense recruitment) of lionfish larvae categorically defined as high-to-low density 'zones'.

Next, occurrence (i.e., presence/absence) data for each of the five selected native GOM groupers and snappers were assembled from the National Marine Fisheries Service's mandatory observer program and the Gulf Southeast Area Monitoring and Assessment Program. Presence data for each native fish species were plotted on a map and subsequently categorized, quantified, and color-coded corresponding to the lionfish sink zones in which they were found. This analysis, therefore, can describe the overall potential vulnerability of each fishery stock to lionfish predation and habitat competition in lionfish sink zones.

RESULTS AND DISCUSSION

Our simulation illustrates that the west Florida shelf (WFS) and nearshore waters of Texas, USA, and Guyana, South America are likely both lionfish sources and sinks (Figure 1). These regions, therefore, should be highest priority for directed lionfish control. The WFS, in particular, was a distinctive region of dense lionfish self-recruitment in the simulation. Adult lionfish are already abundant on the shelf, as noted by both anecdotal and empirical studies (Chagaris et al.

2015, Switzer et al. 2015). As such, dense extant populations on the shelf imply that WFS lionfish may produce more viable larvae than our simulation suggests as we did not consider contemporary abundance. The same is probable in forecasted lionfish larval source locations nearshore Texas and Guyana. Texas lionfish, however, are relatively novel – first reported in 2011– and lionfish have not yet infiltrated Guyana. The larval sinks in all three locations are predominantly in marine waters shoreward of the 50 m depth contour, which is important as presently most lionfish control is through manual removal by divers operating within recreational dive limits of 30 m of water depth or shallower.

Presence data for *E. morio*, *L. campechanus*, *R. aurorubens,* and *M. microlepis*, all were located in high density lionfish sink zones (i.e., zones seven through nine). When summing medium and high risk categories (i.e., zones four through nine), the percentages totaled 97%

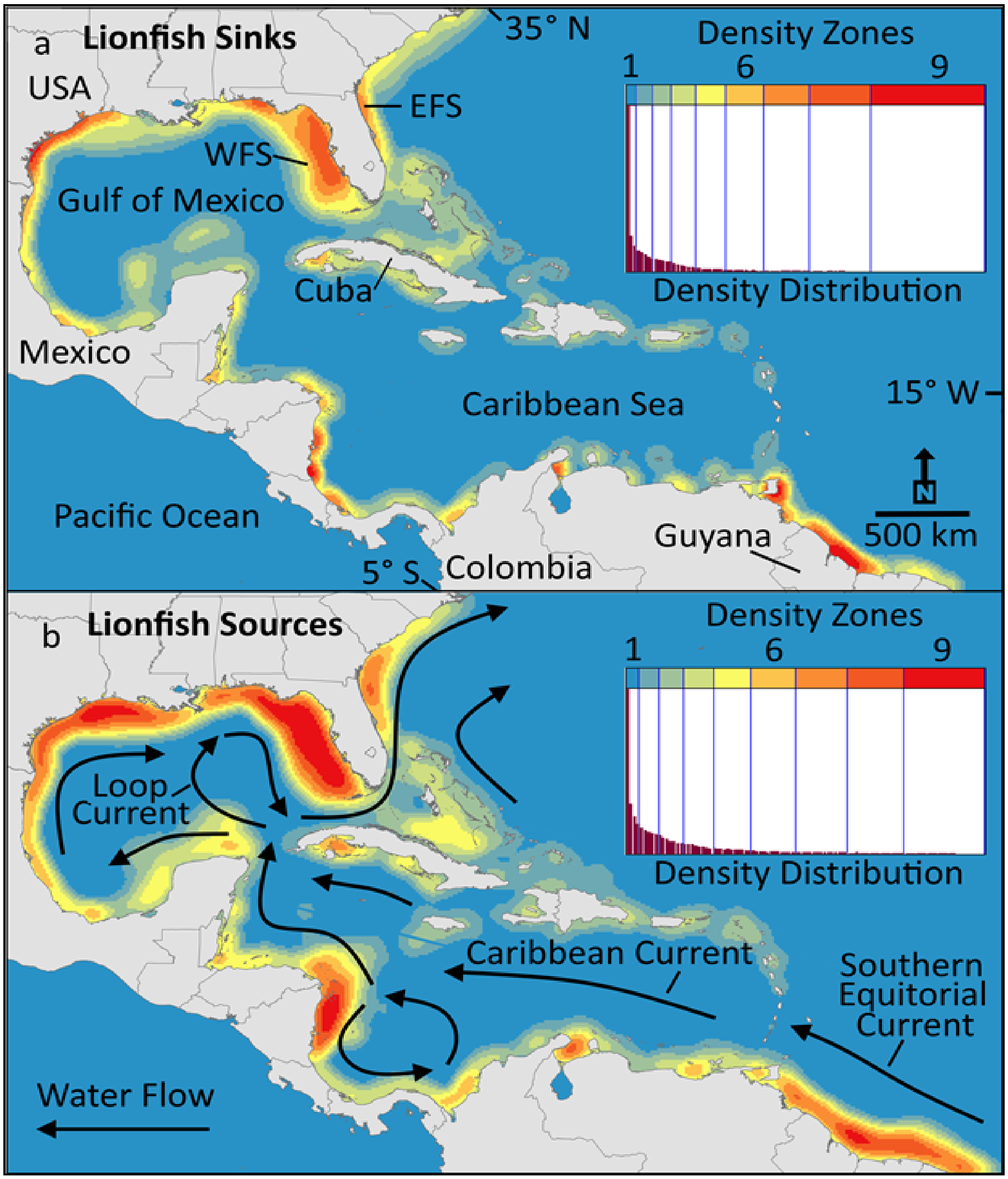

Figure 1. Lionfish Sources and Sinks. Forecasted abundance of lionfish in sinks (a) and sources (b). Relative density is binned into nine density zones for each using Jenk's optimization, with zone one being low (blue) and nine high (red) density. Insets illustrate the zone classification scheme (i.e., zones 1-9) and the distribution histogram of data points. Water flow direction is shown with with black arrows. The West Florida Shelf (WFS) and the East Florida Shelf (EFS) noted.

occupancy for *E. morio*, 88% for *R. aurorubens*, 90% for *L. campechanus*, and 88% for *M. microlepis*. These results suggest that of the five groupers and snappers assessed, the high fishery value *E. morio* (red grouper) is likely to be the GOM species at highest risk from lionfish impacts. Catches of native groupers and snappers, such as those modeled here, contribute billions of US dollars annually to the economies of Atlantic nations, including the commercial value of the fishes themselves and also the associated value-added impacts (i.e., equipment, fuel, boat sales, etc.) that support the fisheries. Understandably, high lionfish biomass and the associated predatory and competitive pressure on native fishes may reduce commercial and recreational catches of snappers and groupers. The consequence may be substantial economic and ancillary damages to the GOM commercial and recreational reef fish fisheries.

Our results suggest that studies to assess direct and indirect lionfish impacts on GOM reef fisheries are of great importance going forward. The data presented here is a forecast of future lionfish densities, based solely on oceanographic features and life strategies of the fish, which may be used to focus lionfish removals as part of a comprehensive management plan. The study data also demonstrate the predatory and competitive pressure that five sympatric groupers and snappers in the GOM may face given the prospect of uncontrolled lionfish populations.

KEYWORDS: Lionfish, coral reef, Gulf of Mexico, monitoring, sanctuary

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