Effects of Invasive Pacific Red Lionfish (*Pterois volitans*) on Bahamian Coral-reef Fish Communities: Preliminary Results from a Large-scale,Long-term Experiment

KEY WORDS: Invasive species, coral reefs, piscivory, community interactions, marine fishes, Bahamas

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Efectos de la Invasión del Pez León Rojo del Pacífico (*Pterois volitans*) en las Comunidades de Peces de Arrecifes Corales de las Bahamas: Un Experimento a Gran Escala y a Largo Plazo

PALABRAS CLAVE: Invasión del Pez León, arrecifes corales, comunidades de peces, Bahamas

Effets de la Rascasse Volante Rouge du Pacifique Envahissantes (*Pterois volitans*) sur les Communautés des Poissons des Récifs Coralliens des Bahamas: Une Expérience à Grande Échelle et à Long Terme

MOTS CLÉS: Rascasse volante rouge, communautés des poissons, récifs corales, Bahamas

EXTENDED ABSTRACT

Previous investigations have shown that invasive Pacific red lionfish (*Pterois volitans*) are generalized predators, consuming a broad diversity of primarily small (less than 5 cm TL) reef fishes (Albins and Hixon 2008, Morris and Akins 2009). In addition, previous experiments conducted on small coral patch reefs have demonstrated that single lionfish are voracious predators of these small fishes, reducing net recruitment of native fishes by 80 to 90% over short time periods (Albins and Hixon 2008, Albins In review). Experiments investigating the effects of lionfish on native coral-reef fish communities have thus far been limited to small patch reefs (several square meters) and short time periods (two months or less), so broader-scale, management-relevant effects remain suggestive. Over time, such drastic effects on the survival of juvenile fishes will likely translate into substantial changes in the adult reef-fish community, both directly by reducing the number of juveniles that survive to adulthood, and indirectly by reducing prey availability for native predators. This outcome could have negative consequences for the resilience of coral-reef ecosystems (Albins and Hixon 2011).

In the spring of 2009, we initiated a field experiment near Lee Stocking Island, Bahamas, to investigate the long-term effects of invasive lionfish on native coral-reef fish communities at a spatial scale relevant to management. Ten large coral reefs (2500 - 5000 m^2) were paired based on habitat similarity (depth, substrate type, position relative to dominant tidal currents, etc.).

One reef in each pair was haphazardly assigned to one of two treatments: high-lionfish-density (HLD) or low-lionfish-density (LLD). Baseline surveys of the coral-reef fish community were then conducted at each reef. Surveys covered a total area of 400 m^2, consisting of two 10 m x 10 m plots and four 2 m x 25 m strip transects at each reef, and were conducted by trained observers on SCUBA. Observers enumerated and identified all fish within these survey areas to the lowest taxonomic level possible, and estimated the total length (TL) of each fish to the nearest cm for fish under 5 cm TL and to the nearest 5 cm for fish over 5 cm TL. After the baseline surveys, all lionfish were removed from LLD reefs and added to HLD reefs. The experimentally augmented density of lionfish on HLD reefs never exceeded "naturally" occurring densities on nearby reefs. After initiation of these treatments, reefs were resurveyed and treatments were maintained at approximately 2 to 4 month intervals year-round.

Based on previous small-scale, short-term experiments, we expected to see a rapid reduction in the density of small prey-sized reef fish via direct predation by lionfish on HLD reefs as compared to LLD reefs. While lionfish are also capable of consuming larger prey on rare occasions (max. observed prey:lionfish size ratio ≈ 0.45 Unpubl. data), there is likely a reduction in predation risk with larger prey body-size, and undoubtedly, some upper size limit (i.e., gape limitation) at which potential prey fish are no longer at risk of predation by lionfish (i.e., a size refuge). Therefore, in addition to an immediate effect of lionfish on small reef fish via direct predation, we expected to see a time-lagged effect on larger fish due to a reduction in the number of small fish surviving to grow into larger size classes (carryover effect). In addition to direct predation and the carryover effect, invasive lionfish may also have a negative competitive effect on the density and/or biomass of ecologically and commercially important native predators, such as snappers and groupers, by reducing the abundance of their prey.

A preliminary analysis of the survey data collected to date, including the baseline survey and five subsequent post-treatment-initiation surveys, illustrates several patterns. First, while the change in density of small (0 - 5 cm TL) native prey -sized reef fish (all species combined) fluctuated across time with peaks in the summer months (due to high recruitment) and valleys in the winter months (due to post-recruitment mortality), summer peaks were greatly reduced on HLD reefs as

compared to LLD reefs (Figure 1a). Second, while the abundance of slightly larger (5 - 10 cm TL) natives did not change substantially on the experimental reefs, lionfish had a temporally sustained negative effect on this size class (Figure 1b). Third, the abundance of larger (10 - 15 cm TL) native fish remained relatively constant on the experimental reefs over time, with no difference between LLD and HLD treatments (Figure 1c).

Although this experiment is ongoing, and the results presented are preliminary, it appears that invasive lionfish are indeed causing rapid and substantial decreases in the density of small native coral reef fish at management-relevant spatial and temporal scales. The negative effect of lionfish appears to be especially strong for the smallest size class of native fishes during peak recruitment seasons, when lionfish effectively reduce summer recruitment pulses toward zero. These results corroborate and greatly extend (both in terms of spatial scale and temporal scale) the results of earlier experiments conducted on small reefs over short time periods (Albins and Hixon 2008, Albins In review). Thus far, the data do not suggest that lionfish have had sufficient time to affect the density of larger sized native fishes. This is not particularly surprising as both potential mechanisms for such an effect (carryover effect and competitive effect) would likely require more time to manifest detectable differences between treatments.

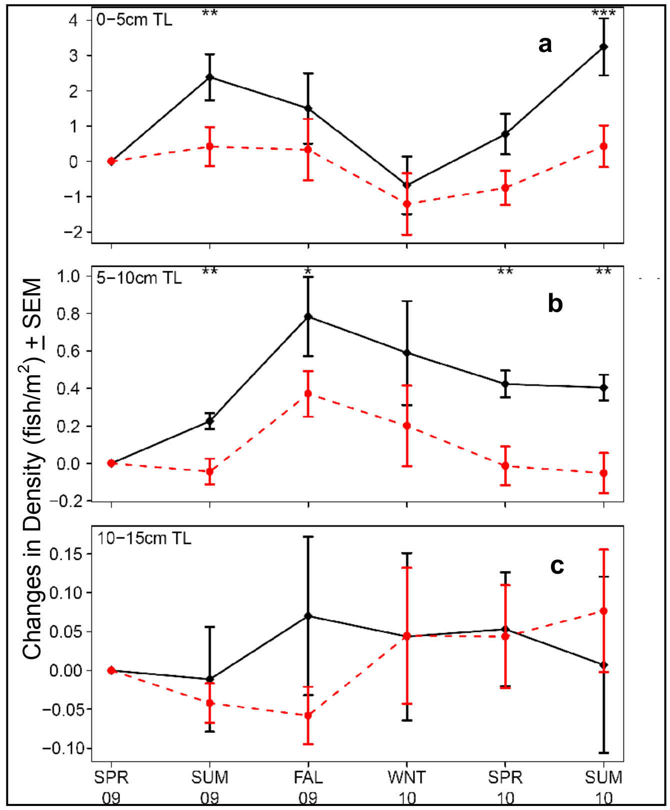

Figure 1. Mean change in density (fish/m^2 ± SEM) of native coral-reef fish (all species combined) in three size classes, (a) 0 - 5 cm TL, (b) 5 - 10 cm TL, and (c) 10 - 15 cm TL, on low-lionfish-density treatment reefs (n = 5, solid black line with diamonds) and high-lionfish-density treatment reefs (n = 5, dashed red line with circles), over the first 15 months of an ongoing experiment. Single asterisk indicates $0.05 < p < 0.1$, double asterisk indicates $0.001 < p < 0.05$, and triple asterisk indicates $p < 0.001$ from preliminary analysis (paired t-tests on individual time steps).