# What Drives the Success of Lionfish Derbies? A Regional Analysis

# Qué Factores Producen el Éxito en los Torneos de Pez León? Un Análisis Regional

# Quels sont les Moteurs du Succès des Concours de Pêche pour le Poisson-lion Invasive? Une Analyse Régionale

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## EXTENDED ABSTRACT

### Introduction

Invasive Indo-Pacific Lionfish (*Pterois volitans/miles*) have now become successfully established in large parts of the North-western Atlantic, Gulf of Mexico and Caribbean (Schofield 2010). Documented lionfish impacts include reductions in richness, biomass and recruitment of native coral reef species, benthic community shifts to algal-dominated reefs, and suggested direct competition with native top predators (Albins and Hixon 2008, Coté and Maljkovic 2010, Green et al. 2014). Natural resource managers now face the unprecedented challenge of dealing with a prolific and versatile invader that can no longer be eradicated from the region. Culling of individuals by spearfishing seems to be the only method to date by which lionfish impacts might be mitigated. Regular culling therefore works as a lionfish control method, but it is logistically intensive (Morris 2012).

Many countries have adopted large-scale lionfish culling programs as a strategy to control lionfish. These efforts usually take the form of lionfish derbies in which concerned citizens, including recreational divers and spearfisher, artisanal fishermen, dive guides, etc., attempt to catch the most or the largest lionfish over a given time period to claim various material and/or monetary prizes. Derbies are occurring haphazardly throughout the region and so far little monitoring of their effect on lionfish populations is occurring. Derbies are by far the largest initiatives to manage the lionfish invasion; therefore, understanding what drives their success is important.

Our goal was to identify the factors associated with successful lionfish derbies. We defined derby success in terms of total number of lionfish captured (i.e., the catch) and total number of participants, reflecting more the social rather than ecological success of lionfish derbies. The widespread implementation of lionfish derbies as tool to control the lionfish invasion makes the results of this study timely and relevant to better understanding and guiding future lionfish management practices.

### Methods

We compiled information on lionfish derbies from the tropical North Western Atlantic, Gulf of Mexico and Caribbean from 2010 to 2015. Data were provided upon request by several derby event organizers. We identified a suite of derby characteristics, as well as attributes intrinsic to the locality where the events took place, which could influence the success of derby events, and generated hypotheses for each of these attributes in relation to success metrics (Table 1).

We used generalized linear models (GLM) with negative binomial error distribution accounting for over-dispersion. We included participant type, time since invasion, and effort as fixed effects in the predictive model of lionfish catch. To model derby participation, we included public type, time since invasion, number of dive shops, and GDP per capita. We developed models to explain hypothesis on derby data available. We used the Akaike's Information Criterion, corrected for small sample size (AICc), selected as top models those with a difference in AICc scores < 2, and averaged coefficient estimates for each parameter across models. All analyses were conducted using the R software.

### Results

*Catch* — Catch values increased significantly with effort and with time since invasion. Catch varied depending on the type of participants involved, and contrary to our prediction, artisanal fishers showed the lowest catches. Catches from derbies involving recreational divers and the general public did not differ, but were higher than those of derbies involving mainly fishers (Table 2). There was a negative interaction effect between effort and invasion timing: at an early to mid invasion stage (0 - 5 years) catch increases with effort, but at longer invasion stages (>10 years) catches reach an asymptote and subsequently a negative relationship with increased effort (Table 2).

*Participation* — Time elapsed since the start of the lionfish invasion at a locale did not predict derby participation number and was not retained in any of the top models. Participation number varied among participant types. Participation number was similar for derbies dominated by recreational divers and those attended by mixed public, but derbies dominated by artisanal fishers were larger. As predicted, participation number increased with the number of local dive shops and with GDP per capita (Table 2).

**Discussion and Conclusions**

Our findings can help to inform the design and implementation of future derbies. For example, if lionfish catch and participation are used as metrics of success, then derbies should be held in areas where lionfish are well established, and where the pool of potential participants is large (e.g., areas with several dive shops). The latter situation might more often, though not always, occur in developed than developing states. Although our results suggest that recreational divers might be more effective lionfish catchers, we hesitate to recommend a wholesale targeting of divers at the expense of artisanal fishers as derby participants. In our study, the type of derby participant was geographically confounded with time since invasion, and it is currently not possible to disentangle these effects. There can be significant benefits to engaging fishers in local marine conservation efforts, e.g. as citizen scientists who can help with early detection of invaders (Lopez-Gomez et al. 2013, Scyphers et al. 2014) which could not be captured in our analyses.

Lionfish derbies are likely to remain an important strategy to control invasive lionfish populations locally and mitigate their effects on native fauna. Awareness campaigns and derby promotion should help increase participation, while judicious choice of the location and/or frequency of derbies should ensure large catches and continued interest by derby participants. Managers and organizers should also allocate resources to estimate lionfish population densities, before and after culls. Only then will we understand more fully the ecological effects of culling tournaments.

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**Table 1.** Variables predicted to influence derby success, expressed as catch (total lionfish captured) and participation (total number of participants).

| | Variables | Data type | Units/Levels | Predictions of event success |
|---|---|---|---|---|
| **Derby variables** | Effort | Continuous | Number of derby participants per time | More participants=more fish captured |
| | Public invited | Categorical | Divers, Fishers, Mixed public* | Catch: Fishers> Mixed public> Divers<br>Participation: Divers>Mixed public>Fishers |
| **Local variables** | Dive shops | Continuous | Number of dive shops in the area | More Dive shops=more participants |
| | Time since Invasion | Continuous | Years since first report of lionfish in the area | More time since invasion=More participants and more fish captured |
| | Gross domestic product per capita (GDP) | Continuous | US$ | Wealthier countries=More participation |

*Mixed public refers to a category that can include similar numbers of recreational divers and fishers as well as other participants such as dive guides, managers, and recreational fishers.

**Table 2.** Coefficient estimates for explanatory variables retained in the best-supported generalized linear models of two metrics of lionfish derby success: 1) catch (number of lionfish caught), and 2) participation (total number of participants). Estimates were obtained through coefficient averaging (see Methods). Log transformed coefficients are in response variable units (i.e. number of lionfish (catch), and number of participants (participation)).

| Response Variable | Predictive Variable | Coefficient Estimate | SE (±) | Log transformed coefficients | SE (±) | Z value | P value |
|---|---|---|---|---|---|---|---|
| **Catch** | Divers | 5.527E+00 | 4.459E-01 | 251.44 | 1.56 | 12.313 | <0.001 |
| | Fishers | -6.088E-01 | 2.481E-01 | 136.79 | 1.28 | 2.408 | 0.0161 |
| | General Public | 9.948E-03 | 2.434E-01 | 253.96 | 1.28 | 0.040 | 0.9680 |
| | Effort | 1.589E-02 | 7.923E-03 | 1.02 | 1.01 | 1.994 | 0.0461 |
| | Time Since Invasion | 1.551E-01 | 6.281E-02 | 1.17 | 1.06 | 2.423 | 0.0154 |
| | Effor:Time Since Invasion | -2.754E-03 | 1.085E-03 | 1.00 | 1.00 | 2.492 | 0.0127 |
| **Participation** | Divers | 2.962E+00 | 3.106E-01 | 19.34 | 1.36 | 9.364 | <0.001 |
| | Fishers | 1.041E+00 | 2.811E-01 | 54.76 | 1.32 | 3.635 | <0.001 |
| | General Public | 3.920E-01 | 2.971E-01 | 28.62 | 1.35 | 1.297 | 0.1948 |
| | # of Dive shops | 8.890E-03 | 3.747E-03 | 1.01 | 1.00 | 2.328 | 0.0199 |
| | GDP per capita | 1.354E-05 | 5.779E-06 | 1.00 | 1.00 | 2.299 | 0.0215 |

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