Feeding Ecology and Prey Selectivity of Invasive Lionfish (*Pterois volitans* and *P. miles*) in Bermuda: What's for Dinner and Why?

Ecología alimentaria y Presa Selectividad del Invasiva Pez León (*Pterois volitans* y *P. millas*) en las Bermudas: ¿Qué es para la Cena y por qué?

L'écologie de l'alimentation et Prey Sélectivité des Envahissantes Lionfish (*Pterois volitans* et *P. miles*) dans les Bermudes: Ce qui est pour le Dîner et Pourquoi?

COREY EDDY[1]*, JOANNA PITT[2], STRUAN SMITH[3], JAMES MORRIS[4], and DIEGO BERNAL[1]
[1]*University of Massachusetts Dartmouth, 285 Old Westport Road, Dartmouth, Massachusetts 02747 USA.*
**coreyeddy1@gmail.com* .
[2]*Department of Environmental Protection, Government of Bermuda, PO Box CR52, Crawl CRBX Bermuda*
[3]*Bermuda Natural History Museum/Bermuda Aquarium Museum and Zoo, PO Box FL145, Flatts FL BX Bermuda*
[4]*National Oceanic and Atmospheric Administration, 101 Pivers Island Road, Beaufort, North Carolina 28516 USA.*

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EXTENDED ABSTRACT

Introduction

As a generalist and opportunistic predator, lionfish have a voracious appetite for anything and everything, consuming large quantities of juvenile reef fish and invertebrates, as well as the adults of small-bodied species. There is great concern that invasive lionfish could cause significant ecological disruption if their populations are not controlled. To better understand the impacts of this species upon invaded ecosystems, we need to understand their feeding habits, diet variation between regions, patterns of prey selection, and how environmental factors may affect diet choice. In this study, we describe the diet of Bermuda's invasive lionfish population based on stomach contents analysis, using indices of prey selection, and by canonical correspondence analysis.

Methods

Between 2012 and 2015, ~1,300 lionfish were collected from multiple locations around the Bermuda platform (Figure 1). Specimens were collected by fishermen, SCUBA divers, researchers, and fisheries professionals using a variety of methods including pole spear, collecting nets, experimental lionfish traps, and as bycatch in commercial lobster traps.

Stomach contents were identified to the lowest taxonomic level possible, counted, and sorted into groups according to that identification. For each individual lionfish, the mass of each group was recorded, but not adjusted for partial digestion, thus these measurements are potentially underestimated. The dietary contribution of each item was calculated as percent frequency of occurrence (% F), percent composition by mass (% M), and percent composition by number (% N). Three indices of importance were calculated:

i) The Index of Relative Importance (IRI),
ii) The Index of Importance (IOI), and
iii) The Index of Preponderance (IOP).

The relative electivity index (E*) (Vanderploeg and Scavia 1970) was used to determine prey selection using stomach contents data and the abundance of species recorded during underwater reef fish surveys conducted at 10, 20, 30, 45, and 60 m. Comparisons were made at the family level and data was pooled by survey depth. We assigned the following E*-values: 1 to 0.1 = positive selection, 0.1 to - 0.1 = neutral selection, and -0.1 to -1.0 = negative selection.

A canonical correspondence analysis (CCA) was used to investigate how diet was influenced by lionfish size (TL), as well as depth, season, and year of capture. The analysis was performed using the *cca* script, available in the software package *vegan* in R.

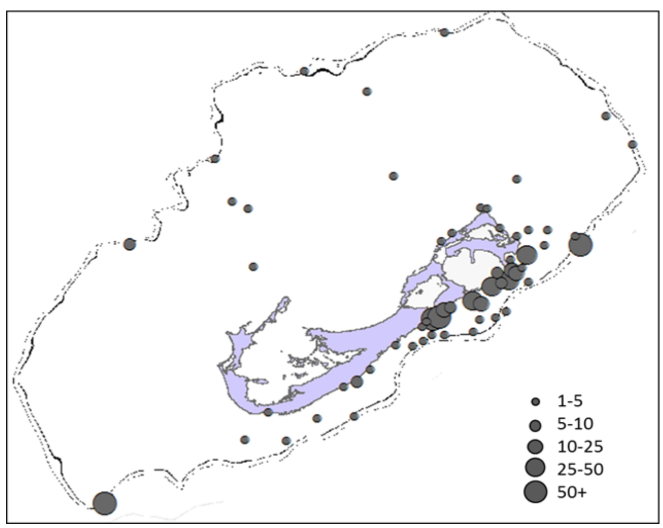

Figure 1. Map of Bermuda showing the locations and numbers of captured lionfish.

Results

Prey composition — In total, 28 teleost species (17 families) and 13 crustacean species (11 families) were encountered. Teleosts accounted for 48.7% N, 40.2% F, and 63.4% M of the lionfish diet. Crustaceans accounted for 49.1% N, 36.8% F, and 32.1% M of the lionfish diet. Unidentified prey items account for 42.9% N, 38.1% F, and 33.7% M.

The red night shrimp (*Cinetorhynchus rigens*) was the most common prey item (16.7% N, 11.8% F, and 20.0% M). The second most common items were *Munida simplex* (8.5% N and 4.2% F) and *Paranthias furcifer* (6.2% M). *C. rigens* and its representative family, Rhynchocinetidae, were ranked as the top prey item, by species and family, for all three indices of importance (IRI, IOI, and IOP).

The E* values ranged considerably for all families in question. Of the four most common families, E* values ranged from -0.4 to .09 for Labridae, -0.9 to 0.5 for Scaridae, -0.7 to -0.05 for Gobiidae, and -0.8 to 0.5 for Chaetodontidae. Scaridae were neutrally selected at 20 m, Labridae at 20 and 45 m, and Gobiidae at 20 m. At all depths (10, 20, 30, 45, and 60m), most families encountered in our surveys were selected against (i.e. E* < 0). There were exceptions. For example, Acanthuridae at 10 m, Synodontidae at 30 m, Scaridae at 45, and Chaetodontidae at 60 m, were positively selected.

Depth and season significantly influenced lionfish diet (Figure 2), corresponding to the first (p = 0.001) and second (p = 0.001) CCA axes, respectively. The first CCA axis explained 53.4% of the diet variance and the second axis explained 24.1%. The third axis explained 13.7% and the fourth axis explained 8.8%, corresponding to size and year, respectively. These correlations were not significantly related (p = 0.117 and p = 0.580, respectively).

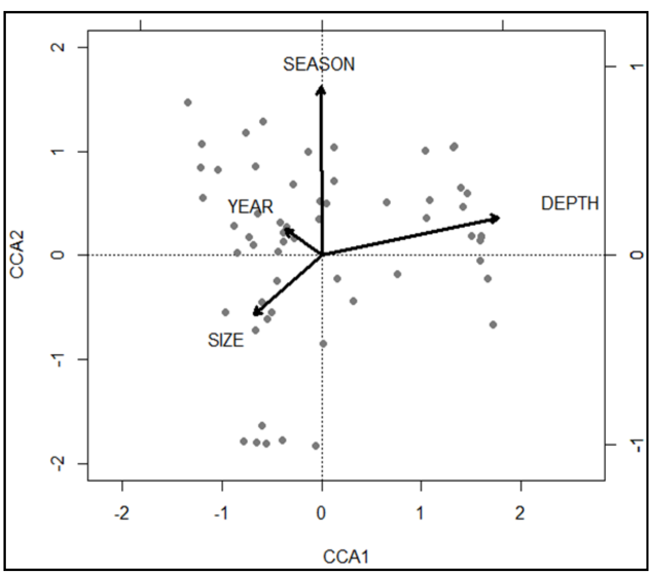

Figure 2. Biplot of canonical correspondence analysis, showing relationship between explanatory variables (season, depth, year, and size) to response variables (prey items). Grey circles represent prey items.

Discussion

In Bermuda, as in all other locations, lionfish consume a diverse range of teleost and crustacean prey. However, compared to other studies, crustaceans make a much greater contribution to their diet in Bermuda. In fact, we believe this is the first study to rank a crustacean as the top prey item, looking at both the family and species level. The frequency at which *Cinetorhynchus rigens* is consumed is alarming considering their minimal contribution seen in Morris and Akins (2009) and their notable absence in many other studies.

Oftentimes, it appears lionfish select their prey based upon characteristic traits mentioned by Green and Cote (2014) and according to their relative abundance. However, it was suggested that Gobiidae would be the most vulnerable prey item, but they were never positively selected in our study. This, and other unexpected trends, could be explained by the abundance of crustaceans in the lionfish diet or the inherent variability in visual survey data.

Overall, it appears lionfish diet is affected by depth and season, but not size. Considering that marine species are known to have depth preferences and specific distributions, as well as the temporal patterns of teleost recruitment and abundance, this seems intuitive.

LITERATURE CITED

Green, S.J. and I.M. Cote. 2014. Trait-based diet selection: prey behaviour and morphology predict vulnerability to predation in reef fish communities. *Journal of Animal Ecology* **83**:1451-1460.

Morris, J.A. and J.L. Akins. 2009. Feeding ecology of invasive lionfish (Pterois volitans) in the Bahamian archipelago. *Environmental Biology of Fishes* **86**:389-98.

Vanderploeg, H.A. and D. Scavia. 1979. Two electivity indices for feeding with special reference to zooplankton grazing. *Journal of the Fisheries Research Board Canada* **36**: 362-365.