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Lionfish (*Pterois volitans* [Linnaeus, 1758]) Show no Diet Preference and Sex Ratio Difference Between the Atlantic and Caribbean Coasts of Vieques, Puerto Rico

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Abstract

Invasive red lionfish (*P. volitans*) were captured by Hawaiian sling in the coastal waters of Vieques Puerto Rico. Specimens were weighed, measured for length, and dissected to determine sex and recover stomach contents for identification. Vieques Puerto Rico has the Atlantic Ocean on the north side, and the Caribbean on the south. We compared the measured parameters and found that there were no significant differences between fishes captured in the Atlantic versus the Caribbean. While there appeared to be a difference in the frequency of invertebrates eaten on two sides of Vieques, it was not statistically significant. This study indicates lionfish living in different habitats have a wide diet and may grow at similar rates in shallow coastal habitats.

Keywords: Invasive red lionfish; Caribbean; Ecozones; Fisher's exact test

Introduction

Invasive species are so commonly reported today that some articles now advocate their impact is both inevitable and less of a problem than previously thought [1]; this is not true for the lionfish (*Pterois volitans*). The lionfish has successfully invaded the Caribbean causing dramatic reductions in biomass and biodiversity of native species [2,3]. Ecosystem disruption and lowered biodiversity have also resulted [4,5]. Reductions in fish catch for human food and recreation have also resulted from the increase of lionfish in the Caribbean [6].

Successful invasive species out-compete native species for resources such as food. One question about invasive species is: are they successful in different habitats in the areas they invade? In other words, does an invasive species utilize resources similarly in different habitats? The island of Vieques provides an opportunity to examine if lionfish have similar life histories and diets in two marine habitats that are spatially close but are substantially different.

Lionfish have spread throughout the Caribbean over the last 30 years, reaching Puerto Rico and surrounding islands about 6 years ago [7,8]. This study examined lionfish from the Atlantic Ocean (south side of Vieques) and the Caribbean Sea (north side of Vieques) to determine if there were any differences in total standard length, sex ratio, or diet. Difference may indicate some variation in life history or food preference that could be used to help control the spread and abundance of this species in the Western Hemisphere.

Materials and Methods

This survey was done in the coastal waters of Vieques, Puerto Rico. This island is 7 km off the southeast coast of Puerto Rico, it is approximately 4.5 km wide and 32 km long with an area of 350 sq. km. The climate is subtropical with a number of ecozones from subtropical wet forest to semi-arid on the eastern end of the island. The climate is similar to other islands in the Greater Antilles group and the North Equatorial Current is the primary influence on the marine habitat [9]. The north coast of Vieques opens to the Atlantic and is shallow to Puerto Rico. The south coast of Vieques is the Caribbean Sea and the water depth drops off to several hundred meters within a few kilometers of the shore.

Lionfish were collected from Vieques, Puerto Rico between May 18 and 21 2015. Fish were collected using hand nets and Hawaiian slings and snorkel gear. Lionfish were captured from five locations around Vieques: Mosquito Pier (18^0 8' 23" N 65^0 30' 36" W), Esperanza Bay (18^0 5' 39" N 65^0 28' 19" W), Cayo Afuera (18° 5' 22" N 65° 28' 20" W), and La Chiva (18° 6' 46" N 65° 23' 14" W). Water temperatures were obtained from a NOAA station on the south coast of Vieques (Station # 9752695) and a buoy 20 km north of Vieques (COICOOS Buoy PR3). These areas were close to shore either in seagrass areas or rocky areas adjacent to seagrass areas [9].

During collection lionfish were stowed in a large (71 × 18 cm) Zoo Keeper [10] containment device. Fish were marked with labeled fishing hooks passed through the lower jaw or caudal fin at the time of capture. Fish that were not killed by capture were euthanized by severing the spinal cord or by pithing. Prior to dissection all fish were weighed using a digital scale. Both total standard length and total length were taken using a fish measuring board.

During dissection all spines were cut off the pectoral, pelvic, dorsal, and anal fins and placed into a bottle for disposal. Dissection of the gut cavity was used to identify sex of the fish. Gonads were located along the ventral side of the swim bladder on the dorsal side of the cavity and identified following Green et al. [11]. The stomachs were removed from the fish and opened for inspection. Prey fish were identified using Humann and DeLoach [12]. Unidentifiable items were not considered in data analysis.

Results

The collection areas are shown in Figure 1 [13]. The collection areas were shallow-water areas amenable to snorkel collection of fish. These are areas are categorized as seagrass areas or colonized pavement/patchy seagrass by NOAA survey [14]. Water temperatures during the test were not measured directly however we have obtained data from two monitoring stations. The Atlantic water temperature was measured by a buoy with a sensor 1m under the surface and recorded an average temperature of 27.9°C during the study period [15]. A NOAA tide level station on the Esperanza pier where some lionfish collection was done has a sensor approximately 1.8 m under the surface and recorded an average water temperature of 28.4 during the study period [16].

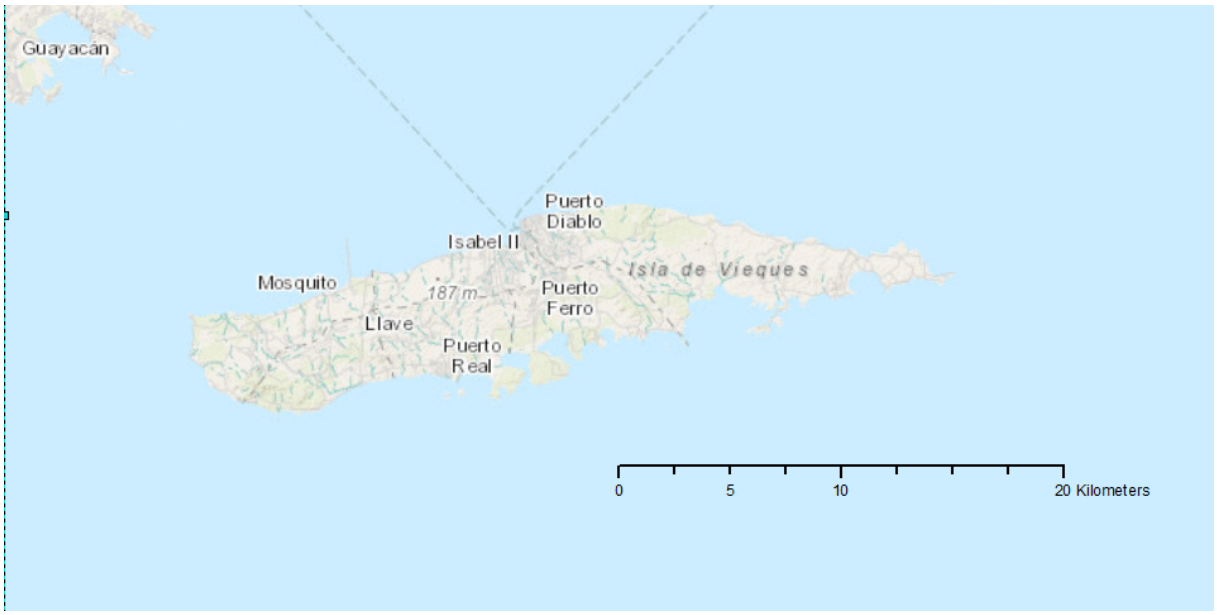

Figure 1: Map of Vieques, Puerto Rico showing location areas, circles, and scale bar [13]. The coast of Puerto Rico can be seen on the west side of the map.

A total of 25 lionfish were captured, 12 females, 11 males, and 2 individuals that were too small to have developed gonads. Table 1 gives the average mass and total standard lengths of the fish are show with standard errors. Anderson-Darling tests for mass and total standard length indicated both sets of data were non-normally distributed ($p = 0.0031$ and $p = 0.0084$ respectively). The data distribution for the mass data was log transformed to normality allowing for t-tests to be conducted on these data. The total standard length data were tested by Mann Whitney U-test.

	All fish	Atlantic side fish	Caribbean side fish
Fish mass	122.3 (± 13.9)	134.0 (± 21.3)	104.8 (± 13.44)
Total standard length	15.19 (± 0.570)	15.73 (± 0.888)	14.38 (± 0.455)
Male mass	152.4 (± 25.8)	165.5 (±32.7)	117.6 (± 36.4)
Female mass	93.7 (± 9.27)	85.70 (± 32.7)	99.4 (± 13.4)
Male length	15.58 (± 0.781)	16.35 (± 0.940)	13.53 (± 0.219)
Female length	14.36 (± 0.424)	13.82 (± 0.545)	14.74 (± 0.603)

Table 1: *P. volitans* masses from the individuals collected in shallow waters of Vieques, Puerto Rico. Masses are in grams with standard errors in parentheses.

The mass t-test showed male and female fish were different weights (t-value 2.09, p-value = 0.0491) with males being heavier. Fish were not significantly different in mass between the Atlantic and Caribbean side of Vieques.

Total standard length (H-statistic = 0.05, p-value = 0.815) and mass (H-statistic 0.03, p-value 0.870) were not significantly different between the two sides of Vieques as tested by Kruskal-Wallis test. There were 5 females and 8 males caught on the Atlantic side of Vieques, while 7 females and 4 males caught on the south coast. When tested by Fisher's Exact test this was found to not be a significant difference ($p = 0.414$).

Thirteen fish had stomachs with undigested contents. They contained 26 prey items, 21 of which were identified. Stomach contents in descending order of abundance were: Atlantic grey shrimp (*Litopenaeus setiferus*), banded coral shrimp (*Stenopus hispidus*), silverside (*Hypoatherina harringtonensis*), sardines (*Harengula humeralis*), and damselfish (*Stegastes varabilis*). Prey items were categorized as either invertebrate or vertebrate for analysis. The occurrence of the two prey types found on the Atlantic versus the Caribbean side of Vieques was tested by Fisher's Exact test. The result, $p = 0.0978$, suggests there was no difference in the prey type being eaten on the two sides Vieques. However this result should be interpreted with caution as the small sample size was small.

Discussion

The only significant difference in lionfish was between the sexes in mass. *P. volitans* collected in shallow water on the two sides of Vieques did not show any significant differences in the other parameters measured. This indicates lionfish appear unaffected by differences in substrate, currents, prey species take, and other aspects associated by living in two different habitats. The similar sex ratio seen on the two sides of Vieques agrees with result seen by Barbour et al. [17] off the coast of North Carolina, where they caught a total of 927 males and 718 females.

These results were unexpected. Other species show that the two marine bodies (Caribbean and Atlantic) that meet in Vieques have distinct differences. While *Rhizophora mangle* (red mangrove) is a tree species, and thus may have less ability to disperse than lionfish, the species has had millions of years in which to intermix genetically around this small island. However, the *R. mangle* on the north side of the island is more similar to Florida populations, over 1,500 km away, than populations on the south side of Vieques, about 10 km away [18]. A similar pattern, though at a larger spatial scale was found to be true of the native giant land crab, Cardisoma guanhumi [19].

Butterfield et al. [20] have done a wide-scale study of the lionfish phylogeographic structure of the Caribbean and Western Atlantic. They found a genetic break between the area of Puerto Rico, the Virgin Islands, and Bonaire and the other areas of the Caribbean and Western Atlantic. The study however did not look at the spatial scale of individual islands or the border between the Caribbean and Atlantic specifically [20].

This study demonstrated how plastic the diets of lionfish can be as well as how shallow-water individuals are similar while living in different marine microhabitats. Their adaptability combined with the ability of a mature female lionfish to produce over 2 million eggs per year contributes to the rapid population growth of this species in new habitats. Only strong human hunting pressure has been found to keep *P. volitans* numbers low, and even this is only partially effective [21].

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