

Diet of the Invasive Pacific Lionfish, *Pterois volitans*, on Natural and Artificial Reefs in the Northern Gulf of Mexico

Dieta del Invasivo Pacífico Pez León, *Pterois volitans*, en Arrecifes Naturales y Artificiales en el Norte del Golfo de México

Diète de la Pacific Invasive Poisson-scorpion, *Pterois volitans*, sur les Récifs Naturels et Artificiels dans le Nord du Golfe du Mexique

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ABSTRACT

Invasive Pacific lionfish, *Pterois volitans*, were first reported in the Gulf of Mexico (GOM) in 2009 and since then have quickly become established on GOM artificial and natural reefs. Lionfish densities on northern GOM artificial reefs are currently among the highest reported in the western Atlantic, while their densities on natural reefs are at least an order of magnitude lower. As part of a broader study examining their impacts on native reef fishes, lionfish (n = 441) were collected with spears by SCUBA divers from March to September 2013 to evaluate differences in their feeding ecology at artificial versus natural reefs (depth range 20 - 40 m). Mean \pm SE total length of lionfish samples from artificial reefs was 231.9 \pm 3.0 mm, and was 225.6 \pm 4.0 mm from natural reefs. Diet analysis revealed 86.7% of stomachs had prey present, with 55% of samples containing identifiable prey that consisted primarily of fish (88.7% of total dry mass) from 15 families. Juvenile vermilion snapper, an important fishery species, constituted 9.5% by dry mass of identifiable fish prey. Lionfish diet was significantly different between natural and artificial reefs (PERMANOVA, $p < 0.001$), with fish captured at artificial reefs having higher percentages of non-reef associated benthic fishes in their stomachs indicating movement of lionfish away from reefs to forage. Ongoing diet work is focused on examining seasonal and ontogenetic effects on lionfish diet, while changes in reef fish community structure and habitat utilization in response to invasive lionfish are being examined in complimentary research.

KEY WORDS: Lionfish, diet analysis, artificial reefs

INTRODUCTION

The extensive and rapid invasion of Pacific lionfish, *Pterois volitans/miles* complex, in the western Atlantic has proven lionfish to be the most successful marine fish invasive species to date. Following their introduction in the 1980s, lionfish first became established along the south Atlantic Bight, followed by the Caribbean Sea, but they were not reported in the Gulf of Mexico (GOM) until 2009 (Schofield 2009, Aguilar-Perera and Tuz-Sulub 2010). Since that time, lionfish have quickly become established residents on both artificial and natural reefs in the northern GOM. Lionfish densities on artificial reefs in the northern GOM have risen to among the highest reported in the western Atlantic (10 - 100 fish/100 m²; W. Patterson, unpublished data), yet their densities on natural reefs remain at least an order of magnitude lower. Lionfish have had catastrophic impacts on native fish populations throughout the western Atlantic owing to the direct consumption of native fishes, including economically important reef fishes, yet the majority of lionfish impact assessments to date have focused on coral reefs that are quite different ecologically from northern GOM reef habitats (Albins and Hixon 2008, Dance et al. 2011). Therefore, local research is important in determining the potential ecological impacts of lionfish on community structure and reef fish abundance (Morris et al. 2009). Additionally, ubiquitous artificial reef habitat in the northern GOM may differ ecologically from natural hardbottom reef habitat within the same geographic area (Carr and Hixon 1997). An understanding of lionfish diet on both natural and artificial reefs is necessary to predict impacts on native reef fish communities, especially fishery species, in the northern GOM. We used stomach content analyses to determine the diet of lionfish and to evaluate for differences in their feeding ecology at artificial versus natural reefs off of northwest Florida, USA.

MATERIALS AND METHODS

Lionfish were collected from natural (n = 8) and artificial (n = 8) reefs south of Pensacola, Florida USA between March and September 2013. All sixteen sites were between 20 - 40 m depth, requiring the use of decompression diving techniques. Lionfish were captured by technical SCUBA divers using tri-tip pole spears then euthanized in a saltwater ice bath. Fish were weighed to the nearest 0.01 kg and measured to the nearest mm total length (TL). Lionfish stomachs were extracted and were preserved in 100% ethanol along with any prey items found in their mouths and gills. White muscle tissue also was dissected and frozen for future stable isotope analysis. Stomach content analysis was performed with a dissecting microscope to identify prey to the lowest taxonomic level possible. Identifiable prey were counted, weighed (wet) and placed in an oven for 48 hours at 70°C to obtain dry mass. Unidentifiable prey samples were weighed (wet) and preserved in 100% ethanol for DNA barcoding, which is ongoing. Wet mass of unidentifiable prey was transformed to dry mass with a

conversion factor calculated from identifiable samples (dry mass = 0.2*wet mass). Identifiable prey was sorted into prey ecology categories: pelagic invertebrates, benthic invertebrates, crustaceans, non-reef associated fishes, reef associated fishes, and pelagic fishes.

A two-factor ANOVA was run to test for differences in lionfish size (ln-transformed TL) by habitat type (natural versus artificial reef) and season (spring versus summer). A permutational multivariate analysis of variance (PERMANOVA) was computed with the Primer statistical package (ver. 6, Anderson et al. 2008) to test for differences in lionfish diet (dry mass by prey category) between natural and artificial reefs.

RESULTS AND DISCUSSION

A total of 441 lionfish was sampled from natural (n = 177) and artificial (n = 264) reefs. Lionfish size ranged from 88 to 377 mm TL. Mean \pm standard error total length was 225.6 ± 4.0 mm for lionfish captured on natural reefs and 231.9 ± 3.0 mm for lionfish captured on artificial reefs. Total length was significantly different between seasons (ANOVA, $p < 0.001$), but neither habitat type (ANOVA, $p = 0.519$) nor the interaction between season and habitat type (ANOVA, $p = 0.279$) were significant (Figure 1). Including unidentifiable prey, 85% of artificial reef lionfish stomachs and 83.1% of natural reef lionfish stomachs contained prey. The percentage of lionfish stomachs containing identifiable prey was 52.0% from artificial reefs and 54.5% from natural reefs. The mean percent diet by dry mass of unidentifiable fish was 52.5% from artificial reef samples versus 45.4% for those sampled at natural reefs. Including unidentifiable fish prey, approximately 95% of the total prey dry mass consisted of fish taxa from 15 different families. Diet of lionfish was found to be significantly different between fish captured on natural versus artificial reefs (PERMANOVA, $p < 0.001$) with clear differences observed in the mean percent diet of reef fish taxa and non-reef fish taxa between habitats (Figure 2). Juveniles of the economically important reef fish, vermilion snapper (*Rhomboplites aurorubens*), were observed in

the diet of lionfish sampled at artificial reefs (19.5% of diet from summer 2013 samples).

Lionfish diet results reported here are consistent with those of other investigators who reported lionfish to be generalist predators that primarily consume demersal or benthic fish (Albins and Hixon 2008, Muñoz et al. 2011, Côté et al. 2013). However, we observed a significant difference in lionfish diet between artificial and natural reefs in that artificial reef samples had a much higher percentage of non-reef fishes present among prey consumed, while prey of lionfish sampled at natural reefs consisted primarily of small demersal reef fishes, such as cardinalfishes (Family: Apogonidae), blennies (Family: Blenniidae), gobies (Family: Gobiidae), and damselfishes (Family: Pomacentridae). Of the reef fish prey consumed by lionfish sampled at artificial reefs, the labrids (pearly razorfish, *Xyrichtys novacula*) and serranids (bank seabass, *Centropristis ocyurus*, and dwarf sand perch, *Diplectrum bivittatum*) actually are reef-associated species that mostly occur over sandy substrates adjacent to reefs. Clearly, stomach contents indicate lionfish were foraging away from artificial reefs on fishes that inhabit sandy substrates, including lizardfishes (Family: Synodontidae), flatfishes (Families: Bothidae, Paralichthyidae, and Plueronectidae), and searobins (Family: Triglidae). This pattern may result from higher lionfish densities on artificial reefs having consumed available reef fish prey (Albins and Hixon 2008), thus forcing them to forage away from reefs. The likelihood of food limitation for lionfish would be inherently greater at artificial reefs given the lower abundance of small demersal reef fishes on northern GOM artificial versus natural reefs (Dance et al. 2011). However, the high densities of lionfish at artificial reef sites, coupled with abundant non-reef fish and invertebrate taxa in their stomach samples, demonstrate their ability to forage on open substrates away from reefs. Acoustic telemetry would seem to be an ideal tool to examine differences in home ranges and foraging behavior of lionfish on artificial versus natural reefs.

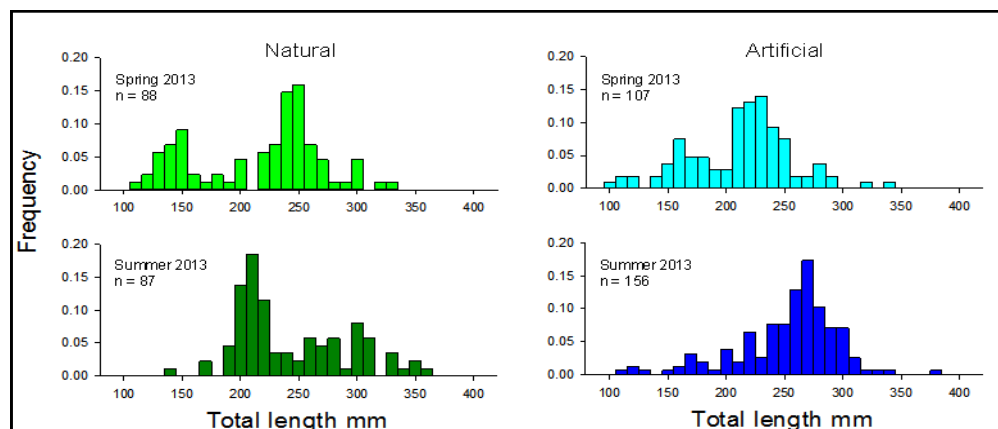


Figure 1. Size distributions by season of lionfish sampled at natural and artificial reefs in the north central Gulf of Mexico.

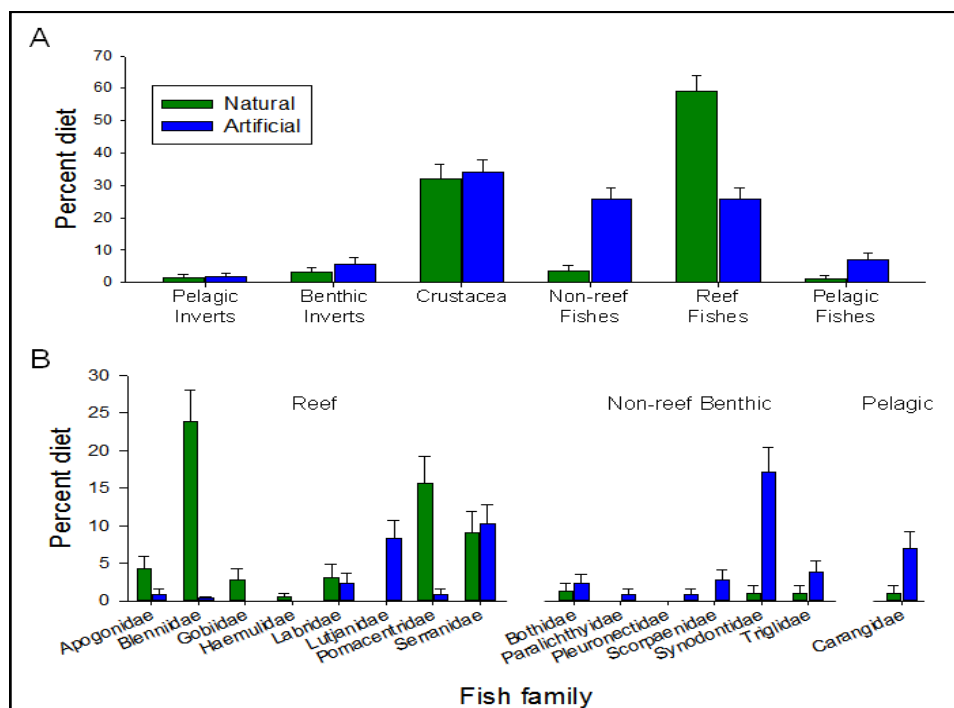


Figure 2. Mean (\pm SE) percent diet (dry mass) of lionfish by A) prey category and B) fish family between natural and artificial reefs. Unidentifiable prey were omitted from percent diet calculations. Fish families are grouped into three clusters representing reef, non-reef benthic, and pelagic taxa.

The greatest contribution of reef fishes to lionfish diet at artificial reefs was juvenile vermilion snapper (Family: Lutjanidae). While a variety of reef fish taxa contributed to lionfish diet on natural reefs, vermilion snapper was the only fishery species observed in lionfish diet from either habitat type. However, beyond direct predation lionfish may be impacting native species indirectly through competition for prey resources or space on the reef. Additional research should focus on these indirect effects, such as differences in native reef fish diet on sites where lionfish have been removed, or examining reef fish foraging behavior on reefs with and without lionfish present.

The large (~50%) percentage of unidentifiable prey among lionfish stomach samples may indicate that diet cannot be accurately estimated based on identifiable prey, especially if softer-bodied prey is digested more rapidly thus less likely to be identifiable. In turn, this could bias estimates of local ecological impacts if inference was made on visually identification methods alone (Côté et al. 2013). We are currently implementing DNA barcoding to estimate species composition of unidentifiable stomach contents which will allow us to more accurately document the diet of northern GOM lionfish. Age and growth analyses are also underway to examine ontogenetic shifts in diet and habitat, as well as to examine the effect of fish density on lionfish size at age.

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