The feeding habits of the Indo-Pacific lionfish *Pterois volitans* at artificial lobster habitats in the Bahamas

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Abstract

The invasive Indo-Pacific lionfish (*Pterois volitans*) is now firmly established in the waters of the Bahamas but little is known of its dietary habits this novel range. In order to assess the risk to the spiny lobster population a survey of lionfish diet was carried out at artificial lobster habitats on the Great Bahama Bank. The stomach contents of 71 lionfish were analyzed by prey type, representing the largest quantitative data set on lionfish diet published to date. Fish were found to make up over 75% of prey. While no lobster remains were identified, traces of shrimp, crab and isopods were found. An increase in piscivory with age was apparent. In comparison with the few previous studies there was an increase in the proportion of fish in the lionfish diet and evidence of diurnal feeding. The naivety of fish prey to the threat of the invasive lionfish is put forward as an explanation for these findings. These results indicate that reef fish, including those of economic interest, are most at threat from this invasion.

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Introduction

The predatory Indo-Pacific lionfish (*Pterois volitans*) is now firmly established in the waters of the Bahamas (Albins and Hixon 2008; Whitfield *et al.* 2007) and continues to spread throughout the Caribbean as far south as Jamaica (USGS 2009). Following the first documented sighting in the Bahamas in 2004 (USGS 2009) lionfish proliferation has continued, with an apparent population surge occurring during 2006-2007 (Albins and Hixon 2008). The probable origins of this invasion lie in the release of aquarium specimens in southern Florida, on one or more occasions in the early 1990's (Ruiz-Carus *et al.* 2006; Semmens *et al.* 2004; Whitfield *et al.* 2002).

The rapid range expansion of lionfish in the western Atlantic Ocean has been facilitated by their generalist diet and the wide availability of prey due to overfishing of competitors (Whitfield *et al.* 2007). In its native habitat this species feeds primarily on fish, crabs and shrimp (Sano *et al.* 1984; Fishelson 1997) and occasionally consumes other invertebrates such as and isopods and gastropods (Harmelin-Vivien and Bouchon 1976). The importance of fish or crustaceans in their diet varies but there seems to be an increase in piscivory with age (Harmelin-Vivien and Bouchon 1976).

Lionfish are ambush predators that use their outstretched pectoral fins to corral prey and then swallow them in a single swift motion (Allen & Eschmeyer 1973; Whitfield *et al.* 2002). They actively forage and appear to be selective hunters that can quickly learn to avoid harmful prey (Dafni and Diamant 1984; Fishelson 1997). Average adult consumption rates of 8.5 g food d^{-1} are reported by Fishelson (1997), although a single individual has been known to consume up to 20 small fish in a 30 minute period (Albins & Hixon 2008). Such intense predation has been shown to have a direct negative effect on the recruitment of coral reef fish in the Bahamas (Albins and Hixon 2008).

The ecological impacts of the lionfish invasion in the Atlantic Ocean are unclear (Whitfield *et al.* 2007) but it poses a threat to important fisheries species such as the Nassau Grouper (*Epinephalus striatus*), which face competition for food and habitat usage (Whitfield *et al.* 2007). With over 50% of the lionfish diet consisting of crustaceans in their native range (Harmelin-Vivien and Bouchon 1976), stocks of spiny lobster (*Panulirus argus*) and stone crab (*Menippe mercenaria*) may also be adversely affected through predation of juveniles. The spiny lobster fishery is particularly valuable to the Bahamas, worth over US$54 million (Buchan, 2000). The documentation of lionfish predation on lobsters in the Bahamas (Adkins 2007) confirms the need for urgent assessment of the risk posed to the spiny lobster fishery.

In order to investigate the potential impacts of the lionfish invasion a survey of their diet was carried out at artificial lobster habitats (also known as condos) used by lobster fishermen on the Bahama banks. These artificial shelters are known as casitas in other Caribbean countries, where they are made of concrete and thatch palm branches (see Eggleston *et al.* 1990) but are functionally identical to condos. They simulate reef crevices, providing protection for the lobsters from predators (Eggleston *et al.* 1990) and act as artificial reefs, attracting fish and other invertebrate fauna (see Eggleston *et al.* 1997, Appendix 1). The objective of this survey was to characterize the diet of lionfish in their invasive range for the first time, allowing an evaluation of the predation risk posed to spiny lobster population.

Materials and Methods

The lionfish survey was carried out throughout the month of August 2008 at various locations on the Great Bahama Bank. Lionfish were collected by divers, using a hook or spear, from lobster habitats during daylight hours only. The artificial habitats were located at depths of 4-16 m and water temperatures were in the range of 29-31°C throughout the survey.

The condos surveyed consisted of rectangular corrugated iron sheets that had slats of wood nailed around three of the edges (Buchan 2000). Commercial fishing vessels in the Bahamas deploy the condos at ~200 m intervals in continuous lines of 200-300 on the seabed. They are selectively deployed on seagrass meadows (see Sosa-Cordero *et al.* 1998) and so all lionfish samples were collected from seagrass dominated benthic environments.

Lionfish were measured (total length ±0.5 mm, TL) and stomachs dissected within three hours of capture. Stomach contents were removed and separated out by eye. All remains of prey were categorized into taxonomic groups, while undigested prey were measured (TL) and identified to their lowest possible taxonomic level. Where possible the length of the spine of partially digested fishes was also measured, although these values were not included in prey size analysis. Spearman rank correlation coefficient of lionfish size and the proportion of prey type was calculated to test for changes in diet with age. For this analysis lionfish were grouped into 25 mm size categories and prey were pooled.

The significance of each prey type in the Lionfish diet was determined using the percentage index of relative importance: %IRI, (Cortés 1997). This compound index is calculated using three indices of importance for each prey type. The percent frequency of occurrence (%O) is multiplied by the sum of the numerical percentage (%N) and the volumetric percentage (%V) to give the IRI for each prey type. This is then expressed as a percentage of the total IRI values for each prey type. The percent volume of each prey type in each stomach was estimated by eye on a graticule glass slide.

Table 1: Relative importance of prey types identified from lionfish (*Pterois volitans*) stomachs (n = 71) by different indices. %O: percentage occurrence; %N: numerical percentage; %V: volumetric percentage; %IRI percent index of relative importance.

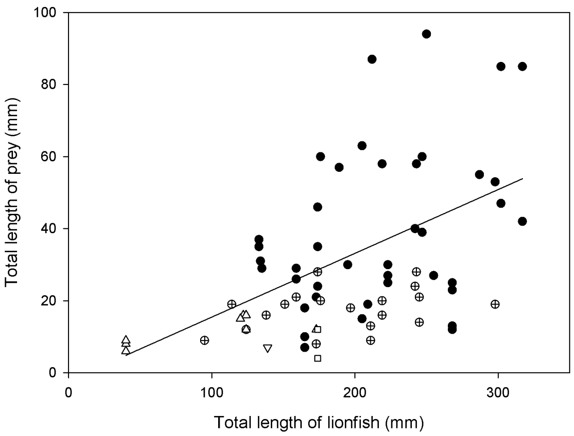
Prey Type	%O	%N	%V	%IRI
Fish	77.36	79.07	78.14	93.98
Shrimp	22.64	17.44	19.31	5.95
Crab	1.89	1.16	1.96	0.05
Isopod	1.89	2.33	0.60	0.02

Results

Prey items were found in 75% of the lionfish that were captured (n=71). The most common prey item found in the stomachs of the lionfish was fish, representing the highest %IRI value, followed by shrimp (table 1). Four species of fish were identifiable, including the slippery dick (*Halichoeres bivittatus*), the lane snapper (*Lutjanus synagris*), the pygmy filefish (*Stephanolepis setifer*) and an initial-phase princess parrotfish (*Scarus taeniopterus*). There was one occurrence of a crab (7 mm carapace width) in stomach contents and on a single occasion two isopods were found in one stomach. Seagrass blades (*Thalassia testudinum*) were found in four of the stomachs, two of which also contained fish. Only one stomach (mostly empty) contained a prey item that could not be positively identified because of its state of digestion.

There was a significant increase in prey length with lionfish length (R^2=0.271, P<0.05), however some of the larger specimens examined contained a wide range of prey sizes (fig. 1). There was also a positive correlation between lionfish length and the numerical proportion of prey that were fish (r_s= 0.93; P<0.01). Other prey types were not abundant enough to demonstrate size relationships but shrimp were found in lionfish that ranged in length from 40 to 270 mm.

Figure 1: Lionfish (*Pterois volitans*) prey lengths. (●) fish, (⊕) fish spine, (△) shrimp, (▽) crab, (□) isopod. Solid regression line defined by the equation y = 0.177x – 2.23 (R^2=0.271, P<0.05). Fish spine data not included in regression.



Discussion

The high feeding rates of lionfish in the Bahamas (Albins and Hixon 2008) pose a serious threat to its benthic ecosystems and in particular those species that are heavily fished. The primary threat posed by the lionfish to the spiny lobster population is through predation of juveniles (e.g. Adkins 2007, Albins & Hixon 2008). The artificial shelters, condos, support a range of lobster sizes (see Sosa-Cordero *et al.* 1998, fig. 6) in the absence of appropriate crevices on the seagrass meadows. While most condos surveyed here contained juveniles and adults, individuals as small as 2-5 cm were often found sheltering in them (personal observation). Despite this food source, no lobster remains were found in any of the dissected lionfish stomachs, indicating that spiny lobster do not make up a significant part of the lionfish diet at conods in the Bahamas.

Fish were the primary component of lionfish diet and all identifiable species are known reef inhabitants. This tendency towards piscivory increased with age, as did the size of fish prey. The crab, shrimp, and isopods were more frequently found in juvenile lionfish (the smallest lionfish found with prey contained three shrimp), probably reflecting the lack of suitably sized fish prey or an ontogenetic shift in diet (Harmelin-Vivien and Bouchon 1976). Although the identity of the shrimp could not be confirmed, two species were commonly found at condos: the banded coral shrimp (*Stenopus hispidus*) and the peppermint shrimp (*Lysmata sp.*); the former is a known prey species of lionfish (Hiatt and Strasburg 1960).

The proportion of fish in the diet of *P. volitans* is higher (>50%) here than previous reports from native-caught fish (Harmelin-Vivien and Bouchon 1976), although Fishelson (1975) classifies it as a piscivourous species. This increase in piscivory may be an indication of prey naivety in recognizing the invasive lionfish as a threat, thus allowing easy capture (Hare and Whitfield 2003). This scenario might also explain the high diurnal feeding activity observed by Albins and Hixon (2008), since darkness would be less important for ambush predation. Though no direct observation of feeding was made here, the finding of virtually undigested prey in the stomachs suggests that ingestion had occurred during the day in some of the specimens. Evidence of diurnal feeing is in contrast to observations of Fishelson (1975), who maintains that lionfish are nocturnal foragers in the Red Sea.

Although the presence of seagrass fragments in the stomachs of piscivorous fish that forage on seagrass beds is not uncommon (Jackson *et al.* 2001, p 274), the finding of large volumes of seagrass (up to four intact blades, folded) in several of the stomachs requires explanation. It may be that the lionfish were feeding on epiphytic invertebrates found on the blades. Several of the blades showed numerous bite marks from smaller fish; however it may have been these small fish that were the prey. Krause and Godin (1995) demonstrated that foraging fish are significantly more likely to be predated upon and less likely to initiate escape behavior than non-foraging fish.

Conclusions on changes in diet are tentative since the only previous studies are based on sample sizes of 16 (Harmelin-Vivien and Bouchon 1976) and 26 (Fishelson, 1997). The approach of tropical storms shortened the anticipated sampling period but the 71 specimens examined here provide an adequate insight into the previously unknown feeding habits of lionfish in the Bahamas for further comparisons. An indication that sampling was sufficient is the finding of relatively minor components of the diet such as isopods and crabs. The data do not allow for categorical denial of predation on spiny lobsters but do support the conclusion that predation pressure on lobsters is minor at conods.

This may not be the case for all habitats and surveys from natural reefs and early-juvenile environments (Acosta and Butler, 1997) are needed to fully assess the risk posed to the spiny lobster population in the Bahamas. Nor may these feeding habits be consistent temporally: as reef-fish populations are depleted the lionfish may turn to other sources of food. These findings and those of (Albins and Hixon 2008) suggest that reef fish (including commercially valuable species) are most immediately threatened by the invasion of lionfish and highlight the urgency for further studies to enable conservation of Bahamian reef ecosystems and fisheries.

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