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FIRST RESULTS ON THE DIET OF THE INVASIVE *PTEROIS MILES* (ACTINOPTERYGII: SCORPAENIFORMES: SCORPAENIDAE) IN THE HELLENIC WATERS

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Abstract. The diet composition of devil lionfish, *Pterois miles* (Bennet, 1828), from the Aegean Sea was investigated. The stomach contents of 42 samples (10 of which were empty) collected between May 2016 and November 2017 from Rhodes Island, Greece, were studied. The diet was composed predominantly of bony fish (78.5% in number, approximately 94.7% in biomass) belonging to a large variety of families, and invertebrates (15.4% in number, 5.1% in biomass), thus indicating an opportunistic feeding behaviour of the species in the study area. The length–length and length–weight relations were also determined.

Keywords: biological invasions, devil firefish, devil lionfish, red lionfish, length–weight relation, stomach content, Mediterranean Sea-

INTRODUCTION

Alien species are considered one of the greatest threats to global biodiversity, because of their potential to directly consume or outcompete native species, alter habitats, affecting detrimentally ecosystem structure and function (Coll et al. 2010, Costello et al. 2010, Bianchi et al. 2012). More than 1000 alien species are listed in the Mediterranean Sea (Giakoumi et al. 2016) and the majority of them are thermophilic species introduced into the eastern Mediterranean basin through the Suez Canal (Katsanevakis et al. 2014).

The devil lionfish, *Pterois miles* (Bennett, 1828), and its congeneric red lionfish, *Pterois volitans* (Linnaeus, 1758), are considered among the most successful invasive alien species in the history of aquatic invasions (Albins and Hixon 2008, Rocha et al. 2015). The devil lionfish, *P. miles*, is a tropical reef-associated species native to the Indian Ocean from south Africa to the Red Sea and east to Sumatra, commercially exploited for the aquarium trade, like the red lionfish, *P. volitans*, native to the western Pacific from southern Japan to western Australia and east to the Pitcairn Group in the south Pacific (Côté et al. 2013, Froese and Pauly 2019). Outside its native range, the species is reported along the south-eastern United States coast from Florida to North Carolina, from Bermuda, Bahamas, and the Caribbean (Schofield 2009, 2010, Johnson and Swenarton 2016), sharing invaded western Atlantic regions with the sister species *P. volitans*. Although genetically distinct, these two species are difficult to be distinguished visually and frequently they are collectively referred to as invasive Indo-Pacific lionfish, invasive lionfish (*Pterois volitans/miles*) or invasive *Pterois* spp. (Schofield 2010, Côté et al. 2013, Johnson and Swenarton 2016, Peake et al. 2018). In the Mediterranean Sea, a single individual of *P. miles* was recorded in 1991 from the coast of Israel (Golani and Sonin 1992). No further observations were made until 2012, when a wave of the devil lionfish invasion started and it is currently ongoing in the eastern Mediterranean, while records are reported up to the central Mediterranean, from Tunisia and South Italy (Azzurro et al. 2017). The lionfish sightings, that followed the common invasion pattern of Lessepsian migrants, and the results of recent genetic studies, are consistent with an invasion of the Mediterranean Sea through the Suez Canal (Bariche et al. 2017). In the Hellenic waters, *P. miles* was firstly recorded from the south-eastern Aegean Sea, in 2009, at Kalymnos Island (Zenetos et al. 2018) and later in 2015 at Rhodes and Crete islands (Crocetta et al. 2015, Dailianis et al. 2016).

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The population of *P. miles* is impressively growing in the Levantine Sea (Azzurro et al. 2017). Due to its abundance in fishing nets and sightings in shallow waters, the species is considered invasive in the south Aegean waters (Zenetos et al. 2018). The purpose of this study was to describe the feeding habits of this Lessepsian migrant in order to give first information on its potential impact on the native food web. Furthermore, data on the length–weight and length–length relations of the species in the area are briefly discussed.

MATERIAL AND METHODS

A total of 42 *Pterois miles* specimens were randomly collected from ten sites, rocky rich of vegetation or sandy-rocky near sparse meadows, located along the east coast of Rhodes Island, from May 2016 to November 2017, at day time (Fig. 1). The majority of the samples were collected in summer 2017 (17 individuals) and autumn 2017 (12 individuals). A total of 36 samples were captured by spear gun at depths ranging from 1 to10 m, while 5 specimens caught by the boat-seining method and one by long line, were captured as deep as 50 m. Specimens were identified following Schultz (1986) and preserved frozen.

Each specimen was thawed and measured. The following parameters were determined, total length (TL), standard length (SL), both with accuracy of 0.01 cm, and wet weight/total weight (TW) with accuracy of 0.01 g. After the removal of internal organs, the net weight (NW, g) was determined. The stomach-intestine was separated and its contents removed. Prey items were counted by number and identified to the lowest taxonomical level possible, depending on the extent of digestion. Fish prey species were identified according to Bauchot (1987). When necessary, prey items were identified from otoliths found in the stomach, following Anàlisi de Formes d'Otòlits (AFORO)[*]. After identification, each prey item was wet weighed with an accuracy of 0.01 g and the length was measured, with 0.01 cm accuracy, by use of a calliper. Given the occurrence of one or more specific items in the stomachs (*F*), the frequency of occurrence (%*F*) of each prey taxa was estimated as the percentage of all stomachs (Hyslop 1980).

The TL values were tested for normality using the Shapiro–Wilk test (when $P < 0.05$ the hypothesis that data follow the normal distribution is rejected). The Pearson's correlation coefficient (r) was calculated in order to determine if the SL–TL and NW–TW relations of the lionfish samples were significantly linearly related. Furthermore, for the length–weight relations of the lionfish, regression analysis was used to test the power curve

$$W = a \cdot L^b$$

where W is TW or NW in g, L is TL or SL, in cm. The analyses were carried out using the statistical program SPSS.

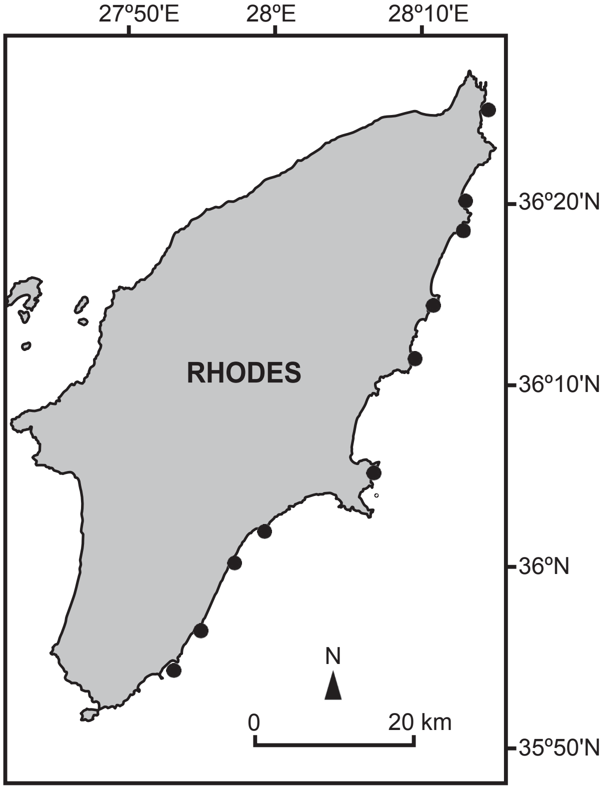

Fig. 1. Sampling sites (●) of *Pterois miles* in Rhodes Island (2016–2017)

RESULTS

In all 42 specimens of the devil lionfish, *Pterois miles* (12 females, 21 males, 9 unsexed), collected from Rhodes, the dorsal fin count was XIII spines and 10 soft rays, the anal fin count was III spines and 6 soft rays.

The TL values of lionfish specimens were normally distributed ($P = 0.094$) and ranged from 14.9 to 31.5 cm, the majority (38 specimens) from 15.0 to 25.0 cm, while the TW ranged from 38.2 to 352.4 g (Table 1). The full stomach weight ranged from 1.1 to 11.7 g, while the empty stomach weight ranged from 0.7 to 8.7 g.

Both the relations between TL and SL and between TW and NW of all the lionfish samples resulted significantly linearly related ($P < 0.001$ in both cases) (Table 2). The power curve was a good fit for the length–weight values of all lionfish specimens ($P < 0.001$), approaching an isometric growth pattern, both for TW–TL ($b = 2.894$) and TW–SL ($b = 3.068$) relations (Table 2).

Among the 42 red lionfish specimens examined, 10 had empty stomachs. A total of 65 items was found in the remaining 32 stomachs. The majority were bony fishes (51 items, 78.5%), partially or well digested, and this rendered difficult their identification and approximate their measurements. Only ten specimens were identified to species, of which five from otoliths. Ten invertebrate items were also detected, 15.4% of total number of prey items, including beaks of Sepiidae, pieces of shrimp exoskeletons, and also the isopod *Nerocila orbignyi*, a common ectoparasite on many of the prey fishes identified (Table 3). Finally, pieces of phytobenthic taxa were observed.

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[*] *http://aforo.cmima.csic.es.*

Table 1

Biometric parameters of *Pterois miles* from Rhodes, Greece

Sex	*N*	Parameter							
		Total length		Standard length		Total weight		Net weight	
		Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
Total	42	14.88–31.52	20.72 ± 3.29	10.80–24.46	15.61 ± 2.42	38.20–352.36	130.12 ± 67.79	31.50–292.48	109.75 ± 57.72
Female	12	16.23–31.52	21.90 ± 3.63	12.33–24.46	16.33 ± 2.94	55.16–330.00	146.49 ± 66.00	5.30–292.48	124.50 ± 59.43
Male	21	15.53–25.80	21.59 ± 2.57	13.41–20.24	16.23 ± 1.77	60.59–352.36	146.45 ± 68.66	51.60–284.10	122.99 ± 57.26
Unsexed	9	14.88–19.03	17.10 ± 1.47	10.80–15.80	13.22 ± 1.48	38.20–122.78	70.18 ± 25.19	31.50–93.60	59.21 ± 19.01

N = Number of specimens, SD = standard deviation.

Table 2

Parameters of the length–length, weight–weight, and length–weight relations for *Pterois miles* from Rhodes, Greece

Equation	*N*	Parameter				
		a	*b*	*r*	R^2	*P*
$SL = a + bTL$	42	1.722	0.670	0.911		0.000
$NW = a + bTW$	42	–0.456	0.847	0.995		0.000
$TW = a \cdot TL^b$	42	0.019	2.896		0.835	0.000
$TW = a \cdot SL^b$	42	0.026	3.068		0.850	0.000

N = number of specimens, TL = total length [cm], SL = standard length [cm], TW = total weight [g], NW = net weight [g], SD = standard deviation, *r* = Pearson's correlation coefficient, R^2 =coefficient of determination.

Fish identified to family, genus, or species were 72.5% of total number of fish prey items, and they belonged to 13 families. The best represented family was Gobiidae, followed by Tripterygiidae, Sparidae, and Labridae and many of the prey items identified are common inhabitants of rocky bottoms or dwell near rocks on sand and seagrasses beds (Table 3). The length of fish preys was measured in 39 items obtained from the stomach of 25 lionfish (Table 4). Fish prey length ranged from 8.9 mm to 70 mm and it appeared that both small and larger fish were consumed by lionfish of different sizes (Tables 3, 4). The TW of food items was approximate, due to the advanced state of digestion of many fish and of the few decapods found. Also, the weight of otoliths found in six cases (total 0.08 g) was not considered. The TW of the remaining 45 fish items was 49.9 g, and contributed approximately to the 94.7% of total food biomass. The higher contribution to the stomach content in weight was observed for Apogonidae, Pomacentridae, and Gobiidae. The weight of invertebrates and phytobenthos was negligible, compared to fish. Among the identified fishes, Gobiidae showed the higher frequency of occurrence in the stomachs (14.3%*F*), followed by Sparidae (9.5%*F*) and Labridae, Pomacentridae, and Tripterygiidae (7.1%*F*) (Table 3). Bony fishes were present in 73.8% of total number of stomachs and in about all the stomachs containing food (96.9%*F*).

DISCUSSION

The devil lionfish, *Pterois miles*, inhabits rocks and coral in its original habitat down to the depth of 50 m, reaching commonly a size between 15 cm and 35 cm (maximum 50 cm) (Golani et al. 2006, Darling et al. 2011, Froese and Pauly 2019). Rocky habitat, range of length and depths of capture of the presently reported study agree with the above-mentioned studies, while mean length and weight obtained appear lower than the majority of those reported in the west Atlantic areas invaded by lionfish (Sabido-Itzá et al. 2016).

The length–weight relation is important in fisheries biology and highly useful in fishery assessment studies (Stergiou and Moutopoulos 2001). In the case of established invasive species, it is essential to document the length–weight relations since they provide information on the changes in time and space of the population in the invaded ecosystem (Sabido-Itzá et al. 2016). Considering that the majority of our samples were collected during summer and autumn 2017 and considering possible variations between regions, seasons, and sexes, the first results of the relation between the weight and length showed an almost isometric growth. The values of the exponent *b* of the power curves obtained in the presently reported study approximated those reported for the native Mediterranean scorpaenids (Stergiou and Moutopoulos 2001, Froese and Pauly 2019), while they were lower than the majority of the values observed for lionfish in various invaded west Atlantic regions (Perera-Chan and Aguilar-Perera 2014, Sabido-Itzá et al. 2016).

Both native and invasive lionfish are primarily crepuscular hunters, especially at dawn or at both dawn and dusk (Fishelson 1975, Jud and Layman 2012, Benkwitt 2016). In the native range juvenile lionfish live in small groups, but as adults they typically occur alone (Fishelson 1975). Recent studies in invaded regions revealed that older lionfish also frequently form groups and furthermore they hunt during the day. Grouping during movement as well as resting in refuges could provide a better defence from predators, while hunting in groups may improve lionfish catch efficiency and increase their feeding success (García-Rivas et al. 2018, Hunt et al. 2019).

Small invasive lionfish show high site fidelity (Jud and Layman 2012), while larger individuals are able to travel from their shelter to surrounding habitats (Benkwitt 2016). High site fidelity may be due to several factors. For example, invaders may not be recognized as predators by native preys, consequently they do not need to move from a specific location searching for food, or lionfish are not recognized as prey by native predators, consequently

Table 3

Number and weight percentage composition of prey items found in the stomachs of 32 *Pterois miles* specimens from Rhodes, Greece

Higher taxon	Family	Species	N	$\%N$	L [mm]	W [g]	$\%W$	F	$\%F$	CMT
Actinopterygii		Actinopterygii gen. spp.	14	21.54	8.9–47.0	12.40	23.36	14	33.33	
	Apogonidae	*Apogon imberbis*	2	3.08	35.6–58.9	6.84	12.78	2	4.76	
	Atherinidae	*Atherina* sp.	1	1.54				1	2.38	O1
	Atherinidae	Atherinidae gen. spp.	1	1.54	10.0	0.70	1.31	1	2.38	
	Bothidae	Bothidae gen. spp.	2	3.08	15.1–15.3	0.81	1.51	1	2.38	
	Centracanthidae	*Spicara* sp.	1	1.54	41.9	0.66	1.23	1	2.38	
	Gobiidae	*Gobius* sp.	4	6.15	20.4–35.8	2.07	3.87	3	7.14	
	Gobiidae	*Gobius niger*	1	1.54	51.1	1.14	2.13	1	2.38	
	Gobiidae	Gobiidae gen. spp.	4	6.15	18.3–22.7	1.31	2.45	3	7.14	O1
	Gobiidae	Gobiidae gen. spp.	9					6	14.29	A
	Haemulidae	*Pomadasys* sp.	1	1.54				1	2.38	O1
	Labridae	*Coris julis*	1	1.54	24.9	0.81	2.93	1	2.38	
	Labridae	Labridae gen. spp.	2	3.08	39.3–42.6	1.86	3.49	2	4.76	
	Mugilidae	Mugilidae gen. spp.	1	1.54	70.0	4.18	7.81	1	2.38	
	Myctophidae	*Notoscopelus* sp.	2	3.08				1	2.38	O2
	Myctophidae	*Notoscopelus bolini*	1	1.54	20.5	2.80	5.23	1	2.38	
	Pomacentridae	*Chromis chromis*	3	4.62	17.0–62.4	5.86	10.95	3	7.14	
	Sparidae	*Lithognathus mormyrus*	1	1.54				1	2.38	O1
	Sparidae	*Pagellus acarne*	1	1.54	32.1	0.50	0.93	1	2.38	
	Sparidae	Sparidae gen. spp.	2	3.08	34.0	3.38	6.47	2	4.76	O1
	Tripterygiidae	*Tripterygion* sp.	2	3.08	26.0–43.4	1.35	2.52	2	4.76	
	Tripterygiidae	*Tripterygion tripteronotum*	2	3.08	37.0–39.1	1.01	1.89	1	2.38	
	Uranoscopidae	*Uranoscopus scaber*	2	3.08	61.0	2.06	3.85	2	4.76	O1
		Total fish	51	78.46	8.9–70.0	49.93	94.65	31	73.81	
Crustacea		Crustacea gen. spp.	2	3.08		0.42	0.71	2	4.76	
	Decapoda Pleocyemata	Pleocyemata gen. spp.	1	1.54	10.0	0.43	0.73	1	2.38	
	Palaemonidae	Palaemonidae gen. spp.	1	1.54	35.7	1.65	2.80	1	2.38	
	Cymothoidae	*Nerocila orbignyi*	2	3.08	3.0–9.0	0.03	0.05	1	2.38	
Mollusca	Sepiidae	Sepiidae gen spp.	2	3.08		0.09	0.15	2	4.76	B
Sipuncula	Aspidosiphonidae	*Aspidosiphon muelleri*	2	3.08	1.8–3.0	0.08	0.15	2	4.76	
		Total invertebrates	10	15.4		2.71	5.06	7	9.52	
Plantae	Posidoniaceae	*Posidonia oceanica*	2	3.08		0.09	0.15	2		
Chromista	Sargassaceae	*Cystoseira* sp.	2	3.08		0.02	0.03	1		
		Total phytobenthos	4	6.16		0.11	0.21	3	7.14	

N = number of prey items, $\%N$ = number of prey items of each taxa expressed as percentage of total number of prey items, L = length range of prey items, W = prey items weight, $\%W$ = percent weight, F = frequency occurrence of each prey item in the stomachs, $\%F$ = frequency of occurrence of each prey taxa as percentage of all 42 stomachs examined), CMT = comments; O = number of specimens identified from otoliths, B = beaks, A = one stomach contained two *Gobius* sp. and one *Gobius niger* specimen.

Table 4

Prey size in respective length classes of *Pterois miles* from Rhodes, Greece

Lionfish		Prey		
N	Total length class [mm]	n	Size [mm]	
			Mean ± SD	Range
10	150–199	15	28.5 ± 12.4	8.9–51.1
13	200–249	21	31.6 ± 16.6	10.0–70.0
2	250–299	3	43.1 ± 21.5	20.0–62.4

N = number of lionfish specimens, n = number of fish prey items, SD = standard deviation.

they do not need to move to escape from them (Jud and Layman 2012). Also, lionfish of small size feed primarily on invertebrates and they do not need to forage far from their site, while they feed mainly on fish when they reach approximately 20 cm TL (Benkwitt 2016).

The majority of the lionfish examined in the presently reported study were caught by spear gun on rocky substrate. Specimens observed and photographed by local divers at Rhodes during the daytime, were solitary and relatively motionless, typically on rocks, sheltering in reef crevices, more often with a head-down posture with open pectoral fins, but also in a sideways or head-up posture and furthermore in horizontal position on sand near rocks. The head-down position is one of the lionfish postures associated mainly with hunting, but also the horizontal and head-up postures are used to catch prey (Côté and Maljković 2010, García-Rivas et al. 2018).

Lionfish are considered opportunistic generalist carnivorous with a broad dietary niche including fishes and invertebrates in the western Atlantic (Côté and Maljković 2010, Peake et al. 2018). This is perhaps one of the reasons they have been such successful invaders in the Caribbean region, combined with other factors such as the long venomous spines that deter predation, their rapid growth, the early maturation and year-round reproduction, the dispersal over long distance during egg and larval stages, the variety of predatory strategies and ecological versatility, as well as prey naivety, weak competitors, and native predators that are overfished and may not recognize lionfish as prey (Côté et al. 2013, Johnson and Swenarton 2016, García-Rivas et al. 2018). In the original habitat, such as the Red Sea and the Gulf of Aqaba, lionfish feed up to a big variety of benthic fishes and also shrimps and crabs (Fishelson 1975, Khalaf and Disi 1997). The results of the presently reported study support the assumption that lionfish in their new Mediterranean environment are not changing their feeding habits, compared both to their native and introduced western Atlantic range. In fact, they are carnivorous and, for the sizes examined in this study (15–31 cm in TL), they were predominantly piscivorous (Benkwitt 2016). The diet was in fact composed by a large variety of small fish species, not only inhabiting rocky bottoms, in caves and crevices, but also dwelling nearby rocks, on seagrasses meadows and also on sandy bottom. These results may indicate that the lionfish are able to forage moving from the rocky habitats where they are usually observed, to nearby different habitats. In conclusion, lionfish are generalist opportunistic ambush feeders, which makes them especially successful predators and can confer high ecological impact on native Mediterranean communities (Galanidi et al. 2018), as dramatically ascertained in the invaded Caribbean ecosystem (Albins and Hixon 2008, Côté et al. 2013).

In their initial stage of invasion, lionfish probably share habitats and food with native Scorpaenidae, such as *Scorpaena scrofa* Linnaeus, 1758 and *Scorpaena porcus* Linnaeus, 1758, which are common in areas similar to those occupied by the lionfish and feed on fish (gobies, blennids) and benthic invertebrates (Bauchot 1987, Golani et al. 2006).

The today's knowledge on the diet of *P. miles*, a newcomer to the Mediterranean Sea, is restricted (Özgür Özbek et al. 2017) and the results of this work add information on this biological aspect that may be useful to evaluate its potential impact on the native biodiversity and food web composition, along which the lionfish appears to be already well integrated.

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