

PARASITISM IN *PTEROIS VOLITANS* (SCORPAENIDAE) FROM COASTAL WATERS OF PUERTO RICO, THE CAYMAN ISLANDS, AND THE BAHAMAS

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ABSTRACT: Recently, *Pterois volitans*, a Pacific species of lionfish, invaded the Atlantic Ocean, likely via the aquarium trade. We examined for internal and external parasites 188 individuals from 8 municipalities of Puerto Rico collected during 2009–2012, 91 individuals from Little Cayman, Cayman Islands, collected during the summers of 2010 and 2011, and 47 individuals from Lee Stocking Island, Bahamas, collected during the summer of 2009. In total, 27 parasite taxa were found, including 3 previously reported species from lionfish, the digenean *Lecithochirium floridense*, the leech *Trachelobdella lubrica*, and an *Excorallana* sp. isopod. We also report another 24 previously unreported parasite taxa from lionfish, including digeneans, monogeneans, cestodes, nematodes, isopods, a copepod, and an acanthocephalan. Among these parasites, several were previously unreported at their respective geographic origins: We report 5 new locality records from Puerto Rico, 9 from Cayman Islands, 5 from the Bahamas, 5 from the Caribbean, and 3 from the subtropical western Atlantic region. Three parasites are reported to associate with a fish host for the first time. The parasite faunas of *P. volitans* among our 3 study sites were quite different; most of the species infecting lionfish were generalists and/or species that infect carnivorous fishes. Although our study did not assess the impact of parasites on the fitness of invasive lionfish, it provides an important early step. Our results provide valuable comparative data for future studies at these and other sites throughout the lionfish's invaded range.

Sightings of Indo-Pacific lionfishes were first officially reported in Florida in the 1980s, likely from the aquarium trade (Semmens et al., 2004), and 2 decades later, Whitfield et al. (2002) reported established populations off the coast of North Carolina. Since then, they have been reported from Cuba (Chevalier et al., 2008), the Dominican Republic (Guerrero and Franco, 2008), Puerto Rico, the U.S. Virgin Islands, the Bahamas, Colombia, Venezuela, Mexico, and the northeastern coast of the United States (Whitfield et al., 2002; Ruiz-Carus et al., 2006; Snyder and Burgess, 2006; Lasso-Alcalá and Posada, 2010). Invasive lionfish include 2 scorpaenid species: the red lionfish, *Pterois volitans* Linnaeus, 1758, and the devil firefish, *Pterois miles* Bennet, 1928. The former species is native to the Pacific Ocean, and the latter is native to the Indian Ocean and Red Sea (Schultz, 1986), with overlap in the Indo-Pacific coral triangle (Kulbicki et al., 2012). Genetic evidence suggests *P. volitans* is the only lionfish present in Puerto Rico (C. Lilyestrom, pers. comm.), the Bahamas, and the Caribbean (Freshwater et al., 2009). *Pterois miles* populations are restricted to the U.S. east coast and Bermuda (Betancur-R et al., 2011).

The strong negative impact of lionfishes on reef communities in their introduced (greater tropical western Atlantic) range (Albins and Hixon, 2008; Green et al., 2012) and their rapid range expansion have stimulated considerable research and debate on the factors that might have facilitated the success of this invasive species, and thus on factors that can potentially regulate their populations (reviews by Albins and Hixon, 2013; Côté et al., 2013). Parasitism is one of multiple factors that can influence the

success of an introduced species, with high parasite resistance in the introduced range facilitating population increase (reviews by Hatcher and Dunn, 2011; Côté et al., 2013) and low resistance inhibiting population increase (Torchin and Mitchell, 2004) and/or affecting host performance (Barber et al., 2000). The susceptibility of introduced species to parasites in the introduced range may also change during the course of an invasion (Torchin et al., 2003; Gendron et al., 2012). A necessary first step in assessing the possible role of parasites in species invasions is to determine the suite of parasites that can infect the invasive species in the introduced range. To date, published studies on parasites of lionfishes have been opportunistic, limited to reports of 1 to several parasites from a small number of specimens. Records of parasites from invasive lionfish in the tropical western Atlantic include a leech attached to the tongue of a male lionfish from Jacksonville, Florida (Ruiz-Carus et al., 2006), which was identified as *Trachelobdella lubrica* Grube, 1840, after reexamination by Bullard et al. (2011); the trematode *Lecithochirium floridense* (Manter, 1934) in lionfish stomachs from North Carolina (Bullard et al., 2011); and an isopod from the genus *Excorallana* from Bonaire (Poole, 2011). Gnathiid isopods were observed infecting lionfish from the Cayman Islands, Virgin Islands, and the Bahamas (Sikkel et al., 2014); however, these were on lionfish held in cages near to heavily infected native fishes, and so these cannot be considered as a record of naturally occurring parasites of invasive *P. volitans*. Here, we present results from a 4 yr study of the parasites of invasive red lionfish that included a total of 326 samples from 3 different island groups. These include Puerto Rico and Cayman Islands (lionfish appeared in 2008 at both sites) (Schofield, 2009), which have not been previously studied, and the Bahamas, where only *Gnathia marleyi* Farquharson, Smit & Sikkelt, 2012, has been previously reported infecting caged lionfish (Sikkel et al., 2014). This study therefore provides the first comprehensive assessment of parasites from invasive *P. volitans* from the broader Caribbean region.

MATERIALS AND METHODS

Collected lionfish were identified as *P. volitans* based only on morphology, based on the assumption that *P. miles* is not present in the

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Caribbean, and it is only restricted to the U.S. east coast and Bermuda (Betancur-R et al., 2011).

Puerto Rico sampling

Lionfish were collected monthly between August 2009 and April 2012 at sampling sites in 8 coastal municipalities of Puerto Rico. These sites included El Escambrón Beach, San Juan (18°27'55.1124"N, 66°5'9.6936"W), Juana Díaz (17°58'10.254"N, 66°29'26.0082"W), Buoy #2, Cabo Rojo (17°55'40.8174"N, 67°12'53.2758"W), Bahía de Mayagüez, Mayagüez (18°12'45.0642"N, 67°11'0.8952"W), Tres Palmas Reserve, Rincón (18°20'56.223"N, 67°15'55.8612"W), Pico de Piedra, Aguada (18°23'9.9024"N, 7°12'43.167"W), Punta Borinquen, Aguadilla (18°29'43.5768"N, 67°9'37.5834"W), and La Parguera, Lajas (17°57'30.9456"N, 67°3'8.7192"W). *Pterois volitans* specimens were caught by recreational diver spearing during the day, immediately placed in individual bags, and stored in a cooler with ice for transport to the laboratory. Lionfish were frozen until processing (within 48 hr of collection). Lionfish were thawed, measured (cm), weighed (kg), and thoroughly examined. Gills were removed, and each arch was processed individually by brushing each of them with small forceps in a solution of 90% tap water and 10% filtered saline water. Gastrointestinal tracts were removed and cut longitudinally, in a petri dish with the same water solution, to expose the insides, and small forceps were used to detach stomach contents and any possible parasites present. Sediment was observed under a dissecting microscope. Externally, fish specimens were placed in a tub with water, and scales were brushed against the grain with forceps and squirted with the water solution to dislodge any parasites from the skin. Then, parasites were identified to the lowest possible taxon and counted. Nematodes were relaxed in glacial acetic acid and stored in 70% ethanol. Isopods and the copepod were preserved in 70% ethanol. Monogeneans were fixed in 10% buffered formalin, and digeneans were fixed in either steaming 10% formalin or AFA (85 ml of ethanol 85%, 10 ml of 100% formalin and 5 ml glacial acetic acid). Cestodes and the acanthocephalan were fixed in 10% buffered formalin.

Cayman Islands and Bahamas sampling

Lionfish were collected off Lee Stocking Island, Bahamas (23°46'00"N, 76°06'00"W), daily from 15 June to 1 July 2009, and Little Cayman, Cayman Islands (19°41'56"N, 80°3'38"W), 8 days in the month of August 2010 (August 4, 5, 6, 8, 12, 17, 19, 22) and 7 days in the month of August 2011 (August 7, 19, 20, 21, 26, 27, 29). All lionfish were collected during the day by scuba divers using hand nets. Each fish was placed underwater in an individual plastic bag and swum slowly to the surface, where it was placed in a plastic tub filled with seawater for transport back to the laboratory. Once at the laboratory, fish specimens were held in flow-through aquaria with unfiltered seawater until processing. All fish were processed for parasites within 24 hr of capture.

Each fish was humanely sacrificed by placing it on a plastic cutting board and severing the brain with a sharp knife, following animal care and use procedures. The entire fish was then placed in a small tub of filtered seawater, where it was measured, and the entire gut and gills were removed. Processing of guts (stomach and intestines) and gills followed the "gut wash" technique of Cribb and Bray (2010). Guts were cut longitudinally and placed in a 250 ml glass container filled with a 150 ml solution consisting of 75% tap water and 25% filtered seawater. Gill arches were placed in another container with the same solution. Both containers were shaken vigorously for 60 sec, and the contents were allowed to settle. The bottom sediment was then siphoned off into a petri dish; the remainder of the liquid was filtered through 53 μ m plankton mesh, and the contents were rinsed into a separate dish and examined for parasites. The remainder of the fish was thoroughly examined for external parasites, including cutting a rectangular patch of scales, 3 cm wide \times 6 cm long, from each side of the fish to sample any parasites living under the scales, and the body cavity was scraped using a scalpel. Parasites were counted and identified to the lowest possible taxon. Digeneans, monogeneans, and cestodes were fixed in 10% buffered formalin, and nematodes and isopods were fixed in 95% ethanol.

Adult and larval parasite stages were found in all study sites (see Table I). To identify all digeneans, a representative of the taxa was dehydrated in a series of ethanol solutions, stained with acetocarmine, and mounted on semi-permanent slides. Monogeneans were mounted unstained in Canada balsam. Cestodes, the acanthocephalan, nematodes, and the copepod were

observed unstained as wet mounts, and isopods were examined whole and unstained under the stereoscope, and high-resolution pictures were taken. Identification of parasites was based on standard keys and primary literature (e.g., Siddiqi and Cable, 1960; Williams and Bunkley-Williams, 1996). Differences in lionfish parasite-collecting techniques from our study areas may have influenced our parasite counts. Voucher specimens of all parasite species found were deposited in the U.S. National Parasite Collection (USNPC), and their accession numbers are provided in Table I.

RESULTS

In total, 188 *P. volitans* specimens from Puerto Rico (total length [TL] between 4.4 cm and 35.6 cm), 91 from the Cayman Islands (TL = 6.8–34.7 cm), and 47 from the Bahamas (TL = 13.4–29.2 cm) were examined. Twenty-seven parasitic taxa were collected from skin, gills, stomachs, and intestines of lionfishes. Eighteen organisms were identified to species, 8 were identified to genus, and 1 was identified to family. Twenty-four of them were previously unreported parasitizing these fishes. One or more taxa was recovered from 145 of 188 (77.1%), 29 of 91 (31.9%), and 21 of 47 (44.7%) of the fish collected from Puerto Rico, the Cayman Islands, and the Bahamas, respectively. Infection location, prevalences, mean intensities, and localities for each parasite species are detailed in Table II. Samples from Puerto Rico and the Bahamas were predominantly infected by digeneans, whereas the Cayman Islands samples were highly infected by digeneans, monogeneans, and cestodes. The digenean *L. floridense* was the most abundant trematode species in Puerto Rico, occurring in 74.5% of the fish (\bar{x} = 13.5 individuals/infected fish), followed by the nematode *Anisakis simplex* Rudolphi, 1809 (11.7%, \bar{x} = 1.36). *Lecithochirium floridense* was also the most abundant species in the Cayman Islands (17.6%, \bar{x} = 2.1), followed by the cestode *Scolex pleuronectis* Müller, 1788 (4.4%, \bar{x} = 10.3) and the monogenean *Udonella caligorum* Johnston, 1835 (3.3%, \bar{x} = 7.3). The didymozoids *Neotorticaecum* sp. Kurochkin and Nikolaeva, 1978, were the most abundant in the Bahamas (19.2%, \bar{x} = 3.4), followed by *L. floridense* (8.5%, \bar{x} = 1.0) and *S. pleuronectis* (6.4%, \bar{x} = 2.67). However, lower prevalences on the Bahamas and the Cayman Islands lionfish could have been an artifact of the open-system aquaria. The possibility of parasite introduction through the water system was unlikely due to the processing time (within 24 hr of collection). Other nematodes, isopods, cestodes, monogeneans, an acanthocephalan, and a leech were also recovered from the 3 localities. *Lecithochirium floridense*, *S. pleuronectis*, *Neotorticaecum* sp., and *Raphidascaris* sp. Railliet and Henry, 1915, were found at all 3 collection sites; *Gnathia* sp. Leach, 1814, was only found in Puerto Rico and the Bahamas; and *Spirocamallanus* species were only found in Puerto Rico and the Cayman Islands (Table II). Five parasites are new locality records for Puerto Rico, 9 for the Cayman Islands, 5 for the Bahamas, 5 for the Caribbean, and 3 for the subtropical western Atlantic region (Table I).

DISCUSSION

There is general agreement that invasive lionfish in the Atlantic are unlikely to be extirpated and that this invader represents a significant source of perturbation of western tropical and subtropical reef communities (e.g., Albins and Hixon, 2008, 2013; Green et al., 2012). Although it is controversial whether predation by Atlantic piscivorous fishes can control invasive lionfish densities (Mumby et al., 2011; Hackerott et al., 2013),

TABLE I. Parasites infecting *Pterois volitans* and their developmental stage, new reports (Puerto Rico [P.R.], the Cayman Islands [C.I.], the Bahamas [B.H.], the Caribbean [Car.], and/or the subtropical western Atlantic [SW Atl.]); number of previously reported hosts (# of hosts) (see Ramos-Trabal et al., 2013; for *Lecithochirium floridense*, see Bullard et al., 2011), and accession numbers (USNPC No.) of vouchers.

Parasite taxon (group)	New reports	# of hosts	USNPC No.
Acanthocephala			
<i>Paracavisoma chromitidis</i> (Cable and Quick, 1954) (adult)	<i>P. volitans</i>	1	107854
Cestoda			
<i>Otobothrium dipsacum</i> Linton, 1897 (adult and plerocercoids)	<i>P. volitans</i>	18	107867
<i>Scolex pleuronectis</i> Müller, 1788 (plerocercoid)	<i>P. volitans</i>	>5	107868
Copepoda			
<i>Chondracanthidae</i> sp. (male) (unknown)	<i>P. volitans</i>	–	–
Digenea			
<i>Bivesicula caribbensis</i> Cable and Nahhas, 1962 (adult)	<i>P. volitans</i> and C.I.	2	107871
<i>Helicometrina nimia</i> Linton, 1910 (adult)	<i>P. volitans</i> and C.I.	20	107874
<i>Lecithochirium floridense</i> (Manter, 1934) Crowcroft, 1946 (adult)	C.I.	>9	107873
<i>Neotorticaecum</i> sp. (metacercaria) Kurochkin and Nikolaeva, 1978 (larva)	<i>P. volitans</i> , P.R., C.I., B.H., Car., and the SW Atl.	7	107872
<i>Pachyreadium crassigulum</i> (Linton, 1910) Manter, 1954 (adult)	<i>P. volitans</i> and B.H.	2	107875
<i>Stephanostomum</i> sp. Looss, 1899 (metacercaria)	<i>P. volitans</i>	3	107870
Hirudinea			
<i>Trachelobdella lubrica</i> Grube, 1840 (adult)	Not a new record	16	107876
Isopoda			
<i>Aegiochus tenuipes</i> (Schiödte and Meinert, 1879) (adult)	<i>P. volitans</i> and C.I.	2	107861
<i>Carpias serricaudus</i> (Menzies and Glynn, 1968) Bowman and Morris, 1979 (adult)	<i>P. volitans</i> , C.I., and first record of association with a fish	0	107866
<i>Eurydice convexa</i> Richardson, 1900 (adult)	<i>P. volitans</i> and first record of association with a fish	0	107863
<i>Excorallana quadricornis</i> (Hansen, 1890) (adult)	<i>P. volitans</i> , B.H., and first record of association with a fish	0	107864
<i>Gnathia</i> spp. Leach, 1814 (larva: praniza)	<i>P. volitans</i>	>17	107865
<i>Rocinela signata</i> Schiödte and Meinert, 1879 (adult)	<i>P. volitans</i>	17	107862
Monogenea			
Gastrocotylinean Post-oncomiracidia Kritsky, Bullard and Bakenhaster, 2011 (larva)	<i>P. volitans</i> , P.R. and Car.	6	107877
<i>Pseudempleurosoma carangis</i> Yamaguti, 1965 (adult)	<i>P. volitans</i> , P.R. and Car.	1	107878
<i>Udonella caligorum</i> Johnston, 1835 (adult)	<i>P. volitans</i> and C.I.	12	107869
Nematoda			
<i>Anisakis simplex</i> Rudolphi, 1809 (larva: L3)	<i>P. volitans</i>	>13	107855
<i>Capillaria</i> sp. Zeder, 1800 (adult)	<i>P. volitans</i> , P.R. and Car.	3	–
<i>Goezia</i> sp. Zeder, 1800 (adult)	<i>P. volitans</i> , B.H. and the SW Atl.	5	107856
<i>Raphidascaris</i> sp. Railliet and Henry, 1915 (adult)	<i>P. volitans</i> , P.R., C.I., B.H., and possibly Car. and SW Atl.	10	107857
<i>Spirocamallanus</i> sp. Olsen, 1952 (larva)	<i>P. volitans</i> and C.I.	–	107860
<i>Spirocamallanus partitus</i> Bashirullah and Williams, 1980 (adult)	<i>P. volitans</i>	1	107858
<i>Spirocamallanus spinicaudatus</i> Bashirullah and Williams (adult)	<i>P. volitans</i>	1	107859

removals by divers offer some hope of at least local control (Barbour et al., 2011; Frazer et al., 2012; León et al., 2013). In any case, invasive lionfish cannot be completely eradicated due to the fact that they occur well below scuba depths (at least 300 m; e.g., Barbour et al., 2011; Albins and Hixon, 2013). Although the lionfish invasion is regrettable, it provides an exceptional opportunity to understand the ecology of host–parasite interactions in general and the role of parasites in species invasions in particular (reviewed in Torchin et al., 2003; Vignon and Sasal, 2010; Dunn et al., 2012; Hatcher et al., 2012). Infections by parasitic organisms remain a possible source of eventual biotic resistance to the lionfish invasion.

In terms of parasitological significance, we report only the second species and second instance of an isopod of the suborder Asollota (*Carpias serricaudus* [Menzies and Glynn, 1968] Bowman and Morris, 1979) (Monod, 1961) to associate with a fish. Before our paper, only 2 species of parasites and 1 genus were known for *P. volitans* in the Atlantic (reviewed in Ramos-Trabal, 2013). We report 27 parasite taxa (Table I). The parasitic faunas of *P. volitans* were quite different across our 3 study islands, with most of the species infecting lionfish being generalists and/or species that infect carnivorous fishes. When comparing the number of species found in common among the 3 island localities, lionfish had 4 species in common among Puerto Rico, the Cayman

TABLE II. Infection location, locality, prevalence (P%), mean intensity (\bar{x} int.), and range of infection of parasite species of the invasive lionfish *Pterois volitans* from Puerto Rico (P.R.) (n = 188), the Cayman Islands (C.I.) (n = 91), and the Bahamas (B.H.) (n = 47).

Parasite taxon	Infection area	Locality	P%	\bar{x} int. (range)
Acanthocephala				
<i>Paracavisoma chromitidis</i>	Stomach	P.R.	0.5	1.00
Cestoda				
<i>Otobothrium dipsacum</i>	Stomach	P.R.	0.5	6.00
<i>Scolex pleuronectis</i>	Stomach	P.R.	2.1	1.00
		C.I.	4.4	10.3 (1–38)
		B.H.	6.4	2.67 (2–4)
Copepoda				
<i>Chondracanthidae</i> sp. (male)	Stomach	P.R.	0.5	1.00
Digenea				
<i>Bivesicula caribbensis</i>	Stomach	C.I.	1.1	1.00
<i>Helicometrina nimia</i>	Stomach	C.I.	2.2	1.00
<i>Lecithochirium floridense</i>	Stomach	P.R.	74.5	13.51 (1–78)
		C.I.	17.6	2.1 (1–7)
		B.H.	8.5	1.00
		P.R.	3.7	2.43 (1–4)
		C.I.	2.2	1.00
<i>Neotorticaecum</i> sp.	Stomach	B.H.	19.2	3.44 (1–21)
		C.I.	2.1	1.00
		P.R.	1.6	1.00
<i>Pachycreadium crassigulum</i>	Stomach	B.H.	2.1	1.00
<i>Stephanostomum</i> sp.	Stomach wall	P.R.	1.6	1.00
Hirudinea				
<i>Trachelobdella lubrica</i>	Gills	P.R.	0.5	1.00
Isopoda				
<i>Aegiochus tenuipes</i>	Skin	C.I.	1.1	1.00
<i>Carpias serricaudus</i>	Skin	C.I.	1.1	1.00
<i>Eurydice convexa</i>	Skin	B.H.	2.1	1.00
<i>Excorallana quadricornis</i>	Skin	B.H.	2.1	1.00
<i>Gnathia</i> sp.	Gills	P.R.	1.6	1.00
		B.H.	2.1	1.00
<i>Rocinela signata</i>	Skin	P.R.	1.6	1.00
Monogenea				
Gastrocotylid post-oncomiracidia	Gills	P.R.	1.6	1.67 (1–3)
<i>Pseudempleurosoma carangis</i>	Esophagus	P.R.	0.5	1.00
<i>Udonella caligorum</i>	Skin	C.I.	3.3	7.3 (1–19)
Nematoda				
<i>Anisakis simplex</i>	Stomach	P.R.	11.7	1.36 (1–5)
<i>Capillaria</i> sp.	Stomach	P.R.	0.5	1.00
<i>Goezia</i> sp.	Stomach	B.H.	2.1	1.00
<i>Raphidascaris</i> sp.	Stomach	P.R.	2.1	1.00
		C.I.	2.2	1.00
		B.H.	2.1	1.00
<i>Spirocamallanus</i> sp.	Stomach	C.I.	2.2	1.5 (1–2)
<i>Spirocamallanus partitus</i>	Intestine	P.R.	0.5	1.00
<i>Spirocamallanus spinicaudatus</i>	Stomach and intestines	P.R.	1.1	1.00

Islands, and the Bahamas, and only 1 parasite in common between Puerto Rico and the Bahamas (Table II). This pattern suggests that a variety of opportunistic parasites are infecting this invasive fish. This finding also means that many localities must be studied in the future to adequately assess the development of the parasitic fauna of *P. volitans* in the Atlantic.

Kennedy and Bush (1994) observed spatial differences in the parasite community composition of the rainbow trout (*Oncorhynchus mykiss*) introduced to eastern North America, South

America, New Zealand, Europe, and different parts of Asia via parasite-free eggs and/or fry. These authors found that the proportion of specialist parasites in rainbow trout declined with increasing distance from the native range and an increasing proportion of generalists, presumably acquired through relatively unrelated sympatric host species. In our case, invasive lionfishes was first reported from Florida, North and South Carolina, and Georgia (Whitfield et al., 2002; Hare and Whitfield, 2003). Although *L. floridense* is not a specialist species, Bullard et al.

(2011) observed a prevalence of 100% of this hemiurid in the 22 lionfish they sampled from North Carolina. However, we found prevalences of *L. floridense* to be 74.5% in Puerto Rico (n = 188), 17.6% in the Cayman Islands (n = 91), and 8.5% in the Bahamas (n = 47). Our lower prevalences could be due to differences in sampling effort, differences in local abundance of the parasite, and/or competition among a more diverse community of intestinal parasites at our sites as compared to those of North Carolina. *Lecithochirium floridense* infects the Atlantic scorpionfish (*Scorpaena plumieri*) as well as unrelated fishes in the Caribbean (*Caranx hippos* [crevelle jack], *Sphyræna barracuda* [great barracuda]) (Williams and Bunkley-Williams, 1996) (*Epinephelus guttatus* [red hind], *Epinephelus morio* [red grouper], *Epinephelus striatus* [Nassau grouper], *Mycteroperca venenosa* [yellowfin grouper], *Mycteroperca microlepis* [Gag], *Abudefduf saxatilis* [sergeant major]) (Bullard et al., 2011).

The cestode *S. pleuronectis* was also relatively common at the 3 study sites. In great quantities, this cestode blocks the bile duct or the gall bladder of its host (Williams and Bunkley-Williams, 1996) and has been associated with the death of *Epinephelus guttatus* (red hind) held in cages in Puerto Rico, where the fish were fed a diet of raw fish scraps. A similar problem was reported in cage-cultured fishes in the northern Gulf of Mexico, when infection intensities ranged from 1 to 9,000 individuals (Williams and Bunkley-Williams, 1996). The voracious appetite of *P. volitans* may result in high accumulation of this trophically transmitted parasite. However, we have seen intensities only ranging from 1 to 38 thus far (Table II), i.e., much lower than the intensities reported by Williams and Bunkley-Williams (1996).

Udonella caligorum had the third highest prevalence in the Cayman Islands, although it is not significantly high (Table II). Several other lionfish (not used for this assessment) were highly contaminated with this monogenean, but this was most likely a result of sharing a holding tank with a native squirrelfish superinfected with *U. caligorum* (>3,800 parasites on the squirrelfish). This finding suggests that this worm has the capacity to switch hosts in a short period of time. This monogenean is a commensal of crustacean parasites of fishes and a parasite of fishes. It is known to damage the gill tissue of cultured fishes and facilitates *Trichodina* spp. (Protozoa) infections (Freeman and Ogawa, 2010). The other parasites we report occurred rarely and thus would appear to have limited potential to regulate *P. volitans* populations at our study sites at this time. However, some of these may become more influential in the future and/or may be influential at other sites in the invaded range. For example, gnathiid species can cause death to highly infected hosts (Davies and Smit, 2001; Davies et al., 2004; Curtis et al., 2013) and transmit blood parasitic protozoans (Mugridge and Stallybrass, 1983; Grutter et al., 2008; Penfold et al., 2008), among other diseases (Jones and Grutter, 2005). However, Sikkell et al. (2014) did not find high prevalences of gnathiids on caged lionfish from the Bahamas.

To make more ecologically relevant comparisons of parasite communities infecting lionfish across their invaded range, future studies should investigate the parasite communities of ecologically similar, native fishes. This will give us insight into the availability of parasites at different localities and how the intensity of parasite infestation might compare between lionfish and native reef carnivores. Furthermore, we know very little about the parasites infecting *P. volitans* in their native Indo-

Pacific region: Only 2 digeneans (Nagaty and Abdel-Aal, 1962; Durio and Manter, 1968; Hassanine, 2006), 2 monogenoids (Paperna, 1972; Ogawa et al., 1995), 2 leeches (Paperna, 1976), and 1 copepod (Dojiri and Ho, 1988) have been documented. A more comprehensive study of lionfish parasites in the Indo-Pacific will not only reveal the degree to which these fishes are susceptible to parasitism, but also whether or not lionfish have introduced any new parasites to the Atlantic region. Although there have not been reports of introduced Indo-Pacific parasites, it does not mean that microparasites might not have hitchhiked in lionfish. So far, only macroparasites have been studied infecting these fishes, except for Anderson et al. (2010), who reported a blood parasite infecting lionfish; however this species has not been proven to be from the Pacific. Even with the introduction of a foreign parasite species, unless there is a suitable host to complete the cycle, the parasite may not become established (Torchin et al., 2003).

The few infections observed during the course of this study may have been a result of the recent presence of lionfish in the Atlantic (Torchin et al., 2003) or due to a highly resistant immune system (reviewed in Hatcher and Dunn, 2011; Côté et al., 2013). Innate and adaptive immune responses help fish control parasite infections (Torchin et al., 2003; Alvarez-Pellitero, 2008). So far, few parasite species are known to infect lionfish in the Pacific (Nagaty and Abdel-Aal, 1962; Durio and Manter, 1968; Paperna, 1972, 1976; Dijiri and Ho, 1988; Ogawa et al., 1995; Hassanine, 2006), probably due to successful immune responses in these fishes even in their native range. Environmental factors (e.g., stress, overpopulation) may benefit parasitic infections in fish (Woo, 1992), and it could be possible that overcrowding of *P. volitans* in their invaded range may be allowing parasites to affect their immunity, thus increasing the number of infections (27 parasite species from our study as compared to previous studies, which report 1 species each). High parasite infections can regulate fish populations by delaying growth and affecting reproductive performance (Barber et al., 2000; Finley and Forrester, 2003; Schultz et al., 2006; Ravichandran et al., 2009). If developing parasite fauna in lionfish keeps increasing, parasite population may control lionfish population in the invaded range. Although our study did not assess the impact of parasites on the fitness of invasive lionfish, it provides an important initial step. Monitoring the development of parasite infestations in this alien host should continue throughout its invaded range and over time.

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