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Back to the Source: Lionfish Imported into the United States via the Ornamental Aquarium Trade

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Abstract

Lionfish (*Pterois miles* and *Pterois volitans*) are known for their invasive success in the western Atlantic and Caribbean. With few marine fish invasions of similar magnitude being documented, the introduction of lionfish in this area has been deemed one of the fastest and most ecologically harmful introductions to date. Furthermore, this invasion is thought to be caused by negligent aquarists who released ornamental lionfish off the coast of Florida in 1985. Interestingly, lionfish are rare in abundance throughout their native waters of the Indo-Pacific and factors controlling lionfish's native populations are little studied and not clearly defined. Through the analysis of the Marine Aquarium Biodiversity and Trade Flow database for the years 2008, 2009, and 2011, it was determined that approximately 137,723 lionfish were exported to the United States with Los Angeles, CA being the most popular point of entry. Of this total, 45.5% originated from the Philippines, 27.7% from Indonesia, and 14.5% from Kenya. *Pterois volitans* was exported from 15 different countries and on average 19 times more than *Pterois miles* which was exported only from three countries. This paper questions: 1) if the ornamental aquarium trade is affecting lionfish's native populations and 2) if the lionfish imports could be leading to more introductions in non-native waters. Ultimately, this paper acts as a short communication identifying a need for further research and attention towards this

Keywords: invasive species, wildlife trade, species introductions

1. Introduction

Lionfish (*Pterois miles* and *Pterois volitans*) have become well-known and widely studied in recent years due to their invasive success. In less than 35 years, lionfish have spread from a few individuals to thousands throughout the western Atlantic Ocean, Gulf of Mexico, and Caribbean Sea (Morris and Whitfield 2009, Schofield 2010, Freshwater et al. 2009, Green et al. 2012, Ferreira et al. 2015). With few marine fish invasions of similar magnitude being documented, the introduction of lionfish has been deemed one of the fastest and most ecologically harmful marine fish introductions to date (Albins and Hixon 2013). Specifically, their success has been attributed to their environmental tolerance, broad appetite, high fecundity, prey naivety, and lack of predators (Morris et al. 2009, Morris and Akins 2009, Green et al. 2011). They are dangerous to local fish communities as their relentless predation disrupts the balance of local ecosystems. For example, a study by Albins and Hixon (2008) saw a 79% reduction in fish recruitment in the presence of one lionfish on experimental patch reefs in the Bahamas in only a five-week observation period. Another study reported lionfish prey biomass reduced by an average of 65% over a two-year-period conducted four years after their initial establishment in the Bahamas (Green et al. 2012). Vast predation by lionfish has shown to result in the over-consumption of herbivore fishes which can lead to coral reef ecosystems shifting to algae dominated (Lesser and Slattery 2011). Presently, lionfish can be found in all marine habitat types and depths as well as live in low salinity conditions (Morris et al. 2012). Furthermore, the lionfish invasion is still ongoing. It is expected that the lionfish will eventually spread to all coastal waters with temperatures above their lethal limit of 10°C (Kimball et al. 2004).

The original lionfish that started the invasion are assumed to have been imported into the United States as part of the ornamental fish trade. Then after some time, negligent aquarists released the lionfish directly into the surrounding waters of the southeast coast of Florida in 1985 (Whitfield et al. 2002, Semmens et al. 2004, Freshwater et al. 2009). The aquarium trade is a now multi-million dollar industry supporting hobbyists and aquarists worldwide. While the industry has given many people in developing nations a source of income, it now being criticized for its unsustainable practices, inconsistent monitoring, and lack of regulation (Rhyne et al. 2012, Dee et al. 2014). Recent estimates suggest that the trade targets 1800 reef fish species from 50 families as well as hundreds of species of stony corals and non-coral invertebrates (Rhyne et al. 2012, Wabnitz et al. 2003). Though some marine aquarium fish are farmed by the industry, over 90% are from wild-caught fisheries (Wabnitz et al. 2003). The vast majority of the marine aquarium livestock originate from tropical oceans in the archipelagos of Indonesia, the Philippines, Sri Lanka, the Maldives, and central Pacific Islands. Others are also imported from the Caribbean and Red Sea regions (Livengood and Chapman 2007). Species are usually collected by divers equipped with hand nets, fish-holding buckets, and barrier nets serving to corral and fence the fishes (Livengood and Chapman 2007). However, concern is growing as it has been reported that divers often use cyanide to capture fishes and if they do dive with compressed air, do so with no regards to dive tables both of which lead to serious health consequences (Wabnitz et al. 2003, Dee et al. 2014). The industry has also disrupted local ecosystems as juveniles and certain sexes are

targeted unevenly and can skew entire populations as such the case with the yellow tang (*Zebrasoma flavescens*) or the Banggai cardinalfish (*Pterapogon kauderni*). Both species were collected to the point that a significant decline in abundance occurred and management efforts had to be put in place with the Banggai cardinalfish now on the endangered species list (Dee et al. 2014, Williams et al. 2009, Lunn and Moreau, 2008).

After collection, fish may spend from a few days to several weeks in 'fish camps' before reaching distribution warehouses. Here, the fishes are typically separated by species, graded by size, and counted while awaiting a local dealer. Once the local dealer collects the species, they are usually maintained in hauling boxes until they reach a secondary holding facility or storehouse (Livengood and Chapman 2007). After their arrival, the fishes are sorted again, placed in oxygenated bags, and air-shipped to major distribution centers throughout the world (Wabnitz et al. 2003, Livengood and Chapman 2007).

Lionfish likely follow a similar supply chain, but little is known about them in their native waters. In fact, they are deemed rare in their native habitat. Most recent reports suggest a max abundance up to 26.2 fish ha-1 in its native range. This is a stark contrast to values up to 400 fish ha-1 in parts of the invaded Atlantic and Caribbean (Kulbicki et al. 2012, Morris et al. 2012). Interestingly, despite the high abundance of lionfish in western Atlantic, Caribbean, and Gulf of Mexico, lionfish are still being imported into the United States through the ornamental aquarium trade. This manuscript acts a short communication in which recent origins and abundance of exports of *Pterois volitans* and *Pterois miles* from various countries within their native geographical range to the United States with hopes to bring attention to impacts this may have on both the native and invasive populations.

2. Methods

Data was obtained through the Marine Aquarium Biodiversity and Trade Flow database compiled and made available by Rhyne, Tlusty, Holmberg, and Szczebak (2015). These researchers evaluated and cross-referenced trade data from over 29,000 shipments entering the United States (Rhyne, Tlusty, Holmberg, and Szczebak 2015). This resulted in the creation of detailed dataset containing number, import location, and export location for hundreds of species. This database can be viewed publicly online at https://aquariumtradedata.org/

For this study, the years 2008, 2009, and 2011 were explored from this database as these were the years that complete 12-month datasets were available. Due to only having complete datasets for three years, the following assumptions should be recognized: (1) The pressure from the aquarium trade is continuing and has been consistent on lionfish in the past; (2) The species *P. miles* and *P. volitans* are being correctly identified from each other; (3) Lionfish are being removed from their native waters near their origin of export location.

3. Results and Discussion

Collectively for the years 2008, 2009, and 2011, 137,723 lionfish were imported the United States. Of this total, 45.5% originated from the Philippines, 27.7% from Indonesia, and 14.5% from Kenya (Table 1.). *Pterois volitans* was the more abundant export of the two

species. On average, *Pterois volitans* was exported 19 times more than *Pterois miles* (Figure 1.). It was also observed that *P. miles* was only exported from three countries, Sri Lanka, the Philippines, and Indonesia, while *P. volitans* was exported from 15 countries with the Philippines, Sri Lanka, Indonesia, and Kenya being the top exporting countries. Both species were imported significantly less in 2008 than in 2009 and 2011 (Figure 1.). The port of entry data showed that Los Angeles, CA was the most popular port for both *P. miles* and *P. volitans*. After Los Angeles, the abundance at port of entry locations varied for the two species with San Francisco, CA and Chicago, IL being the 2nd and 3rd main ports for *P. miles* and New York, NY and Miami, FL for *P. volitans* (Figure 2., Figure 3.).

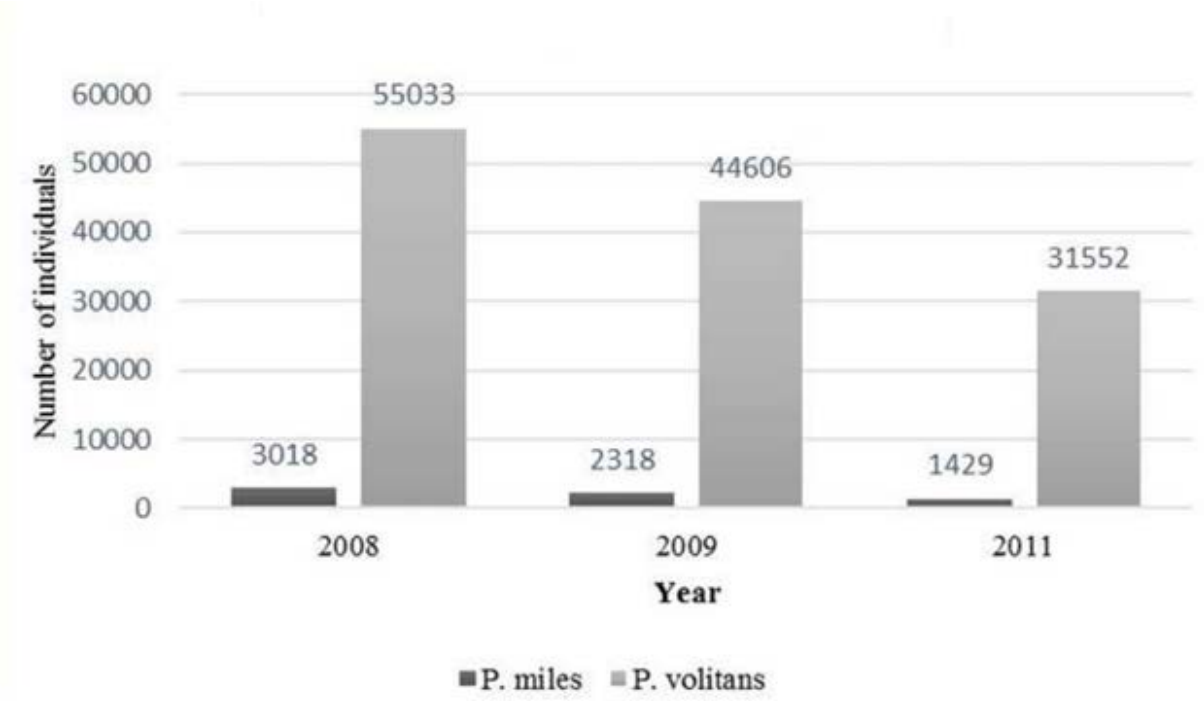

Figure 1. Collective total lionfish exported from Indo-Pacific to the United States for species *P. miles* and *P. volitans* for years 2008, 2009, and 2011

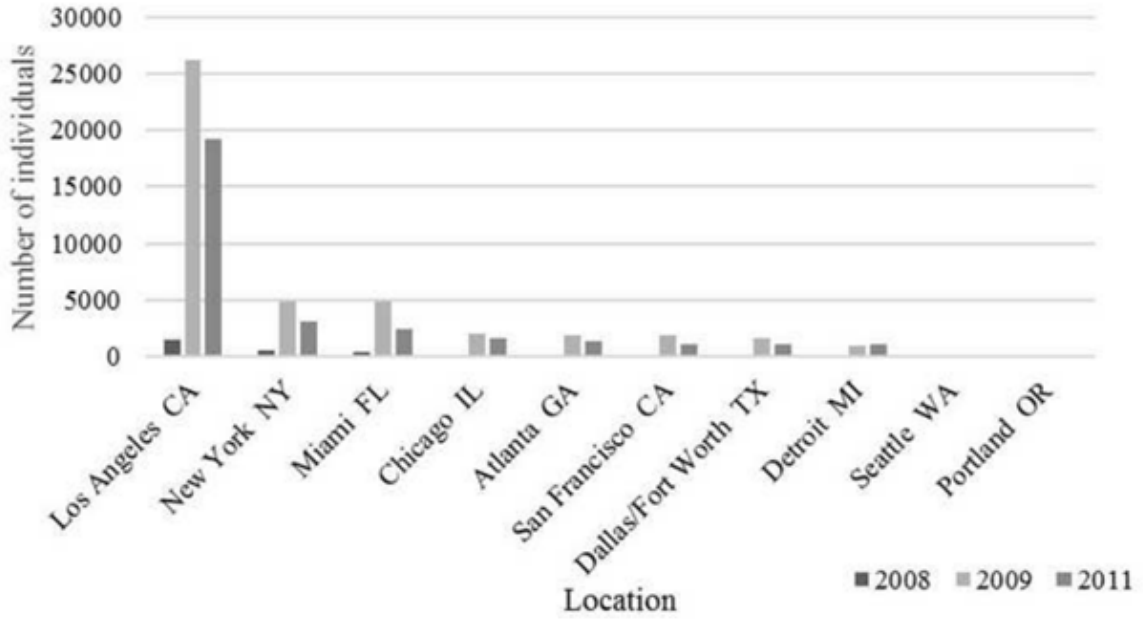

Figure 2. *Pterois miles* abundance at various ports of entry for years 2008, 2009, and 2011

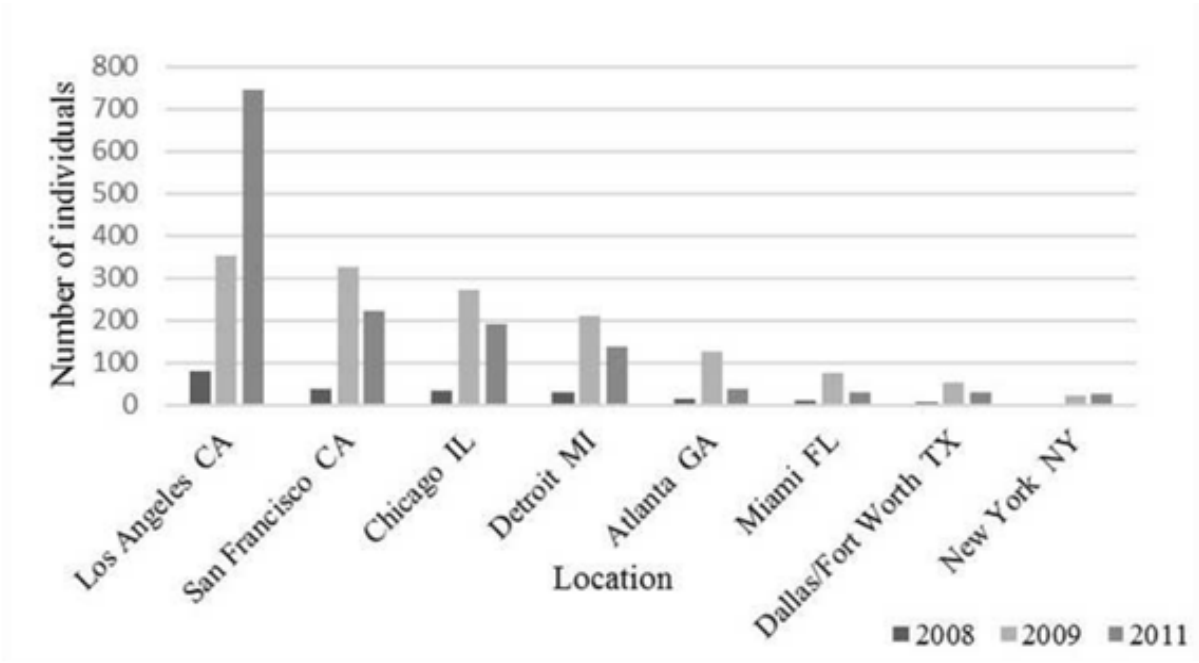

Figure 3. *Pterois volitans* abundance at various ports of entry for years 2008, 2009, and 2011

Table 1. Collective lionfish (*P. miles* and *P. volitans*) export totals to the United States by origin for years 2008, 2009, and 2011

Lionfish export totals by origin		
Origin	Number	Percent
Philippines	62,451	45.3453
Indonesia	38,177	27.7201
Kenya	20,075	14.5763
Sri Lanka	15,776	11.4548
Vietnam	897	0.6513
Solomon Islands	151	0.1096
Papua New Gui	139	0.1009
Kiribati	18	0.013
Eritrea	13	0.0094
Vanuatu	8	0.0058
Micronesia	6	0.0043
Tonga	5	0.0036
Maldives	4	0.0029
Fiji	2	0.0014
Australia	1	0.0007
Total	**137,723**	

Overall these results show that in a relatively short period, a mass number of lionfish were consistently brought into the United States. The observation that *P. volitans* was more favored than *P. miles* is likely due to their different geographic ranges within the Indo-Pacific. *P. volitans* occupies a large area throughout the south Pacific whereas *P. miles* is more constrained to the Indian Ocean (Kulbicki et al. 2012). *P. volitans* also is more aggressive of the two species which likely contributes to its abundance (Cure et al. 2012). This is also true in the invaded area as about 93% of the Atlantic population of lionfish consists of *P. volitans*, while only 7% is *P. miles* (Hamner et al. 2007). The differences seen in the values of the species imported could also be attributed to the species being misidentified. Both species look and behave very similarly; they both appear to have red and white zebra-like stripes, long pectoral fins, venomous spines, and a sedentary, fearless demeanour (Schultz 1986). However, meristic counts differ between the species. *P. miles* generally has 10 dorsal-fin rays and 6 anal-fin rays while *P. volitans* usually has 11 dorsal-fin rays and 7 anal-fin rays (Schultz 1986). The low import values seen for both species in 2008 are likely due to the financial crisis that shook the U.S. and many other nations from 2007-2008. The popular port of entry locations likely also attributed to the species geographic ranges. *P. volitans* commonly ended up being imported to cities on the west coast (e.g. Los Angeles, San Francisco) of the United States whereas *P. miles* was seen to enter on the east coast (e.g. New York). The results presented here only represent lionfish exports to the United States. The abundance of exports of lionfish to other countries are not known to the same degree. Assuming that there are other countries also importing lionfish, then it is likely even more lionfish are being removed from its natural habitat. While, the limits, controls, and drivers of native lionfish populations is not well known, the aquarium trade could be factor (Kulbicki et

al. 2012, Cure et al. 2012). Furthermore, investigating the collection methods and techniques how over 100,000 lionfish have been removed alive is needed. If these fishes were removed with adverse methods such as cyanide, then the collection of lionfish would be directly threatening both coral ecosystems and human health.

Perhaps the biggest question raised by this data is the final whereabouts of the imported lionfish after passing through its port of entry within the United States. As of current, the only state to ban the importing of lionfish is Florida. This is concerning as the lionfish invasion affects much of the US southern and eastern coastline as well as US territories. If any of the imported lionfish end up in the hands of negligent aquarists—again, more introductions could be occurring within the already invaded area. Alternatively, the aquarium trade industry could potentially help fight the invasion if the sourcing for ornamental lionfish shifts to the invaded area rather than the Indo-Pacific. Presently, lionfish removals have been shown to be the most effective way to control population in the invaded areas. However, these removal efforts are most often done through spearing and limited to diving conditions (Ali et al. 2013, Ali et al. 2015, de León et al. 2013).

Insofar, this manuscript poses more questions than answers, but offers many directions and implications for future research. Gaps in the data regarding years and other countries importing lionfish need to be filled. The final location of imported lionfish should be monitored as any other introductions in nonindigenous waters could fuel the invasion. Policy on importing lionfish should be re-evaluated if the risks of other introductions are found to be high. More information on lionfish in their natural habitat should be collected, especially in regards to population dynamics. Overall, as the lionfish invasion continues to spread and managers continue to try and mitigate it, the original cause of the invasion—the ornamental aquarium trade— should not be forgotten.

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