

Geographic extent and chronology of the invasion of non-native lionfish (*Pterois volitans* [Linnaeus 1758] and *P. miles* [Bennett 1828]) in the Western North Atlantic and Caribbean Sea

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Abstract

The Indo-Pacific lionfishes (*Pterois volitans* [Linnaeus 1758] and *P. miles* [Bennett 1828]; Family Scorpaenidae) are the first non-native marine fishes to establish in the Western North Atlantic. The chronology of the invasion is reported here using records from the US Geological Survey's Nonindigenous Aquatic Species database. Currently, lionfish are established off the Atlantic coast of the USA from the Florida Keys to Cape Hatteras (North Carolina), the Great Antilles, Bermuda, Bahamas, Cayman Islands and Turks and Caicos. The species have been reported from only one island in the Lesser Antilles (St. Croix), but it is not yet established there. Lionfish are established in Mexico, Honduras and Costa Rica. Reports have come from the Gulf of Mexico (Florida), Belize, Panamá and Colombia; although lionfish are not considered established in these localities at this time (August 2009), invasion is likely imminent.

Key words: lionfish, *Pterois volitans*, *Pterois miles*, non-native marine fishes, Scorpaenidae

Introduction

The Indo-Pacific lionfish species (*Pterois volitans* [Linnaeus 1758] and *P. miles* [Bennett 1828]; Family Scorpaenidae) are the first non-native marine fishes to establish in the Western North Atlantic and Caribbean Sea. Although there are both confirmed and unconfirmed (anecdotal) reports of lionfish sightings from decades past, it is only recently (i.e., since 2000) that the species have considerably increased in numbers and spread through the Western North Atlantic (Whitfield et al. 2002, 2007; Freshwater et al. 2009a). At this time it is unclear what effects this new addition will have on native communities, and because the invasion is so recent there are few ecological studies of its impact (but see Albins and Hixon 2008). Nonetheless, there are several reasons to be concerned about their presence: Lionfish are predators that consume native species (Morris

and Akins unpubl. data) and have venomous spines that could injure divers. In this paper, information on the chronology of invasion of the lionfish is provided using records from the US Geological Survey's Nonindigenous Aquatic Species database (USGS-NAS 2009).

Material and Methods

The USGS-NAS database is the national repository for spatially-referenced sightings information for non-native aquatic species in the USA (USGS-NAS 2009). The Reef Environmental Education Foundation database (REEF 2008) and National Oceanic and Atmospheric Administration (NOAA) are major contributors of lionfish data to the USGS-NAS database. Records in the USGS-NAS database are derived from a variety of sources, including scientific literature, published and unpublished reports, museum specimens and personal communi-

cations. Data provided in this report is as current as possible; however, as lionfish distribution changes through time it is likely to become outdated. Lack of sightings data for a given region should not be inferred as a reduced number of lionfish in that region (see Haiti, below). Additionally, the number of reports for a given area may not be reflective of density of lionfish, as likelihood of reporting varies from place to place. Reporting frequency may be a function of the number of divers or tourists that visit a location, therefore places with well-established dive operations and facilities for tourists are likely to have increased reporting. For the most current information, visit the USGS-NAS database online (USGS-NAS 2009). Individuals who have relevant information concerning lionfish (or other non-native fishes) are encouraged to report their findings to the USGS-NAS database.

In the early stages of the invasion, it was thought that only one species of lionfish was present (*Pterois volitans*). However, recent genetic evidence has indicated that *P. volitans* along with a small number of *P. miles* are present in the Atlantic Ocean (Hamner et al. 2007; Morris and Freshwater 2008; Freshwater et al. 2009a, b). It is not clear whether both species are present in all locations; thus in this paper both species are referred to as “lionfish”.

Results

Locations where lionfish are established

Atlantic Coast of Mainland USA

The first confirmed record of lionfish occurrence in the USA was a specimen taken by a lobster fisherman off Dania, Florida in October 1985 (Morris and Akins *In Press*). The next time lionfish were reported was the liberation of six specimens from a sea-side aquarium in south Florida that was damaged in Hurricane Andrew in August 1992 (Courtenay 1995). Reportedly, these lionfish found their way into Biscayne Bay, where they were observed alive a few days later. In his 1995 report, Courtenay also mentioned that lionfish had been seen in three other south Florida locales (Lake Worth, Palm Beach, Boca Raton) but no additional details are given. After Courtenay's 1995 report, there were no sightings of lionfish in the USA until 2000, when they were observed off Palm Beach (Florida, $n = 4$), South Carolina ($n = 1$), and three locations off

North Carolina ($n = 1$ fish per locality). In 2001 lionfish were seen in three locations in Florida (Jupiter, $n = 1$; Palm Beach, $n = 3$; Jacksonville $n = 1$), off the Georgia coast ($n = 3$), at three locations off South Carolina ($n = 1$ to 4 fish per location), at 14 sites off North Carolina and as far north as Fire Island, New York ($n = 2$). By 2002, lionfish were considered more or less continuously distributed from Miami, Florida to Cape Hatteras, North Carolina. Assessments of these populations have been reported by Whitfield et al. (2002, 2007), Meister et al. (2005) and Ruiz-Carus et al. (2006).

Occasionally, small lionfish have been collected north of North Carolina (e.g., coastal New Jersey, Rhode Island and New York), presumably swept northward in the Gulf Stream. However, these individuals are not expected to survive due to their intolerance of cold winter temperatures (Kimball et al. 2004).

Lionfish were not found in the Florida Keys (from Miami south to the Marquesas Islands) until relatively recently (January 2009); much later than they were found in significant numbers along the Atlantic coast of Florida north of Miami. The first Florida Keys lionfish was found at Benwood Ledge (near Key Largo) in 66 ft of water. The specimen was collected within 24 hrs of the sighting. Twelve additional lionfish have been seen as of June 2009; most of these have been collected by REEF (REEF 2008).

Bermuda Islands

The first lionfish recorded from Bermuda was a juvenile taken from a tide pool on the southern shore of the island in 2000 (Whitfield et al. 2002). It appears the species persisted at low levels for several years, as only a few lionfish were seen each year between 2001 and 2003. By 2004, lionfish were numerous in Bermuda. Although lionfish continue to be seen regularly in Bermuda, their annual densities seem to vary greatly. It is unclear whether lionfish can overwinter in Bermuda, and thus unclear whether the population is established (i.e., a self-supporting reproductive population) or transient (driven by recruitment via the Gulf Stream).

Commonwealth of the Bahamas

Lionfish first appeared in the Bahamas in 2004 at Nassau (New Providence Island). By 2005 they had established and spread to the Abacos, Andros, Eluthera, Exumas and San Salvador islands. Lionfish inhabit the whole of the

Bahamas now, including not only the typical coral reef habitats, but also mangrove, seagrass, sandy beach and occasionally even canal habitats.

Lack of genetic differentiation between Bahamian and North Carolina *P. volitans* suggests they share a similar source (e.g., east coast of Florida; Freshwater et al. 2009a). While both *P. miles* and *P. volitans* occur off the US Atlantic coast (Hamner et al. 2007; Morris and Freshwater 2008); thus far only *P. volitans* has been recovered from Bahamian waters (Freshwater et al. 2009a).

The effects of non-native lionfish on invaded ecosystems has not been widely studied. However, Albins and Hixon (2008) showed that lionfish could drastically reduce recruitment of native fishes on small patch reefs in the Bahamas. Green and Côté (2008) documented lionfish densities off New Providence Island that were more than eight times greater than known from the native range. A diet study of Bahamian lionfish was completed by Morris and Akins (in press) that showed lionfish primarily eat teleost fishes (they documented 41 species in 21 families) as well as some crustaceans (about 15 % of the diet by volume). Also in the Bahamas, lionfish were found in the stomachs of groupers (Maljković et al. 2008). However, it is unclear how common predation on lionfish occurs.

Turks and Caicos Islands

The initial report of lionfish from the Turks and Caicos islands occurred in May, 2006; however, the specific location of the report was unclear. The first confirmed lionfish report from the Turks and Caicos islands was a single specimen seen in August 2007 off West Caicos. Five additional sightings were reported in 2007. More than 25 sightings of lionfish were reported in 2008 and 23 additional reports have been added to date to the USGS-NAS database in 2009 (through July).

Cayman Islands

The first lionfish record for the Cayman Islands was a single juvenile seen in February 2008 off Little Cayman Island. The specimen was removed by government officials a few days later. The second lionfish found in the Cayman Islands was captured from a reef off Cayman Brac in October 2008. The Cayman Islands Department of Environment has begun an aggressive lionfish removal programme, using local divers that are specially trained and

licensed to remove lionfish. As of June 2009, over 200 lionfish have been captured and removed from the Cayman Islands.

Republic of Cuba

In 2005, a snorkeler spotted a juvenile lionfish in very shallow water on the Atlantic coast of the island after the passage of Hurricane Katrina, but the report was never confirmed. The first confirmed reports of lionfish in Cuba were in 2007. Chevalier et al. (2008) documented the species at six localities along the Atlantic (northern) coast and two from the province of Santiago de Cuba on the southeastern (Caribbean) coast of the island. Six additional reports of lionfish from the Atlantic coast and two from the Caribbean (Camaguey and Granma) were reported in 2007. In 2008, lionfish were reported from more than twenty localities around the island. Over 20 sightings have been reported in the first six months of 2009, and many of these are from the southwestern (Caribbean) coast where lionfish were not previously found. Sometimes as many as 15 individuals were seen on a single dive.

Jamaica

The first confirmed report of lionfish in Jamaica was the sighting of a single specimen at Runaway Bay on the northern coast of the island in March 2008. More than 20 additional reports were received in 2008, and an additional 44 reports have been received so far in 2009 (between January and mid-August).

Dominican Republic

The first confirmed report of lionfish from the Dominican Republic was from Sosua Bay, Puerto Plata (northern coast), in May 2008 (Guerrero and Franco 2008). There were several unconfirmed reports of lionfish from Sosua Bay previous to this; however, the report of Guerrero and Franco (2008) provided the first photo-documented evidence of the species in the Dominican Republic. The authors reported that more than 20 additional specimens had been observed between the time they photographed the one in May 2008 and the time their paper was published (July 2008). Reports from the USGS-NAS database document the species' spread across both the northern and southern coasts of the island in 2008. Lionfish have been reported from 18 additional locations between January and mid-August 2009.

Commonwealth of Puerto Rico

The first confirmed report of lionfish from Puerto Rico was in November 2008, when a single individual was spotted off Vieques Island. Twenty more sightings have been reported between January and mid-August 2009.

Mexico

Two lionfish were reported from Cozumel Reefs National Marine Park in January 2009. Since then, 26 more lionfish reports have come from Cozumel. Fourteen additional reports of lionfish have documented their spread along the Mexican mainland west and south of Cozumel in 2009.

Honduras

The first lionfish known from Honduras was a specimen captured in May 2009 off the island of Roatán inside the barrier reef about 200 m from shore in 7 m of water. Seventeen additional sightings have been reported from Roatán thus far and 4 reports have come from Utila (as of August 2009).

Republic of Costa Rica

Lionfish were first seen in Costa Rica in April, 2009 at the Manzanillo Wildlife Refuge (n=3). Additional specimens were seen the following month at two nearby locations (Puerto Viejo [n=2] and Cahuita National Park [n=4]). An additional 23 reports have come from Cahuita National Park and 12 additional reports from Manzanillo Wildlife Refuge in 2009.

Locations without enough information to determine establishment

Republic of Haiti

There are only five lionfish records from Haiti. The first was in August 2008, when a specimen was photographed near a jetty in water 2-3 m deep on the western side of Hispaniola (Gulf of Gonâve). Three more reports in April 2009 documented a total of five fish on the northern coast at Labadee (also written as "Labadie"; near Cap Haïtien). A report from June 2009 documented ten more individuals near Baie de l'Acul. The relatively small number of records in the USGS-NAS database is probably not because there are fewer lionfish in Haiti, but likely due to low reporting from this area. Lionfish are classified as established for Hispaniola largely due to the fact that there are reliable records from the Dominican Republic. However, there is

not enough information from Haiti to make a specific determination as to their status there.

Locations where lionfish have been seen but have not yet established

US Virgin Islands

The first lionfish records from the US Virgin Islands were from a diver who saw and photographed several lionfish at two sites off the north shore of St. Croix in June 2008. However, these records have been disputed. In November 2008 a juvenile lionfish was collected off the Frederiksted Pier, on the western side of St. Croix. Between January and July 2009, seven more fish have been seen or collected from St. Croix. At the time of this publication, no lionfish have been seen in proximity to St. Thomas or St. John.

Gulf of Mexico

In October 2006, a dead lionfish was retrieved from waters off Treasure Island (Pinellas County), Florida (FWRI 2008). The fish was found during a bloom of the toxic red-tide organism *Karenia brevis*; however, toxicity testing revealed only minimal exposure of the fish to the brevetoxin. Therefore, it appears the fish was only in Gulf coast waters for a short period of time. Several other reports of lionfish in the northern Gulf of Mexico (from Texas and the Florida panhandle) have been received by the USGS-NAS database; however, to date none of these have been confirmed.

Belize

There was an unconfirmed report of a lionfish sighting in Belize from September 2001. The first confirmed report was a single specimen taken in December 2008 from Turneffe Atoll. Subsequently, lionfish have been seen at Glover's Reef (January 2009; n=1), Ambergris Caye (March 2009; n=2) and Lighthouse Reef (June 2009; n=3).

Republic of Panamá

Three lionfish have been collected from Bocas del Toro, the first in May 2009 and the second and third in July 2009. All three specimens were donated to the Smithsonian Tropical Research Institute in Bocas del Toro.

Republic of Colombia

The first lionfish from Colombia was seen on a shallow (5 m) patch reef in December 2008 at

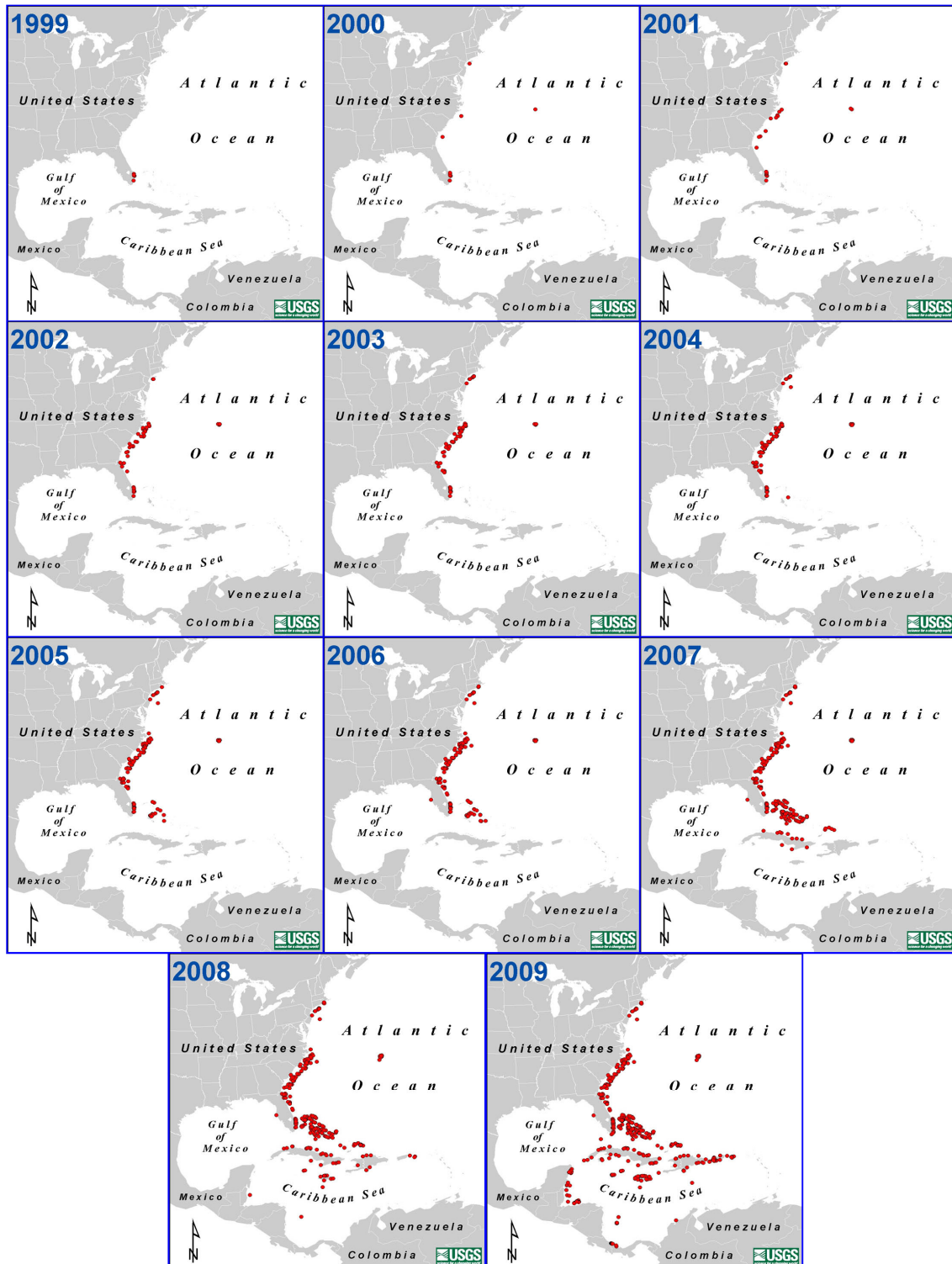


Figure 1. Confirmed lionfish occurrences in the Western North Atlantic and Caribbean Sea (USGS-NAS 2009). The first panel displays all lionfish records in the database through December 1999 ($n=5$). Each subsequent panel displays cumulative occurrences of lionfish for each calendar year. The panel for 2009 includes data through mid-August 2009. All data is available online via the USGS-NAS database (<http://nas.er.usgs.gov>). Alternately, this [direct link](#) is available

Manta City just south of Isla de Providencia in the Seaflower Biosphere Reserve, part of the Archipelago of San Andres (near Nicaragua). Nine additional specimens have been seen off San Andres Island to date. In May 2009 two specimens were collected at Tayrona National Park, Santa Marta. These two fish were the first known from the Colombian mainland; at least one of these is deposited in the Museum of Natural History (INVEMAR). Four additional fish have been seen near Santa Marta off the Colombian (mainland) coast (González et al. 2009).

Summary

Figure 1 displays cumulative lionfish occurrence information by year, summarized below:

Atlantic Coast of USA: Lionfish have been established from Miami to North Carolina since 2002. They have only recently (2009) established in the Florida Keys. Although present in Atlantic waters north of North Carolina, they are not considered established there because they are not likely to survive cold winter temperatures.

Bermuda, Bahamas, Turks and Caicos and Cayman Islands: Lionfish were numerous in Bermuda by 2004 and established in the Bahamas by 2005, the Turks and Caicos by 2008 and the Cayman Islands by 2009.

Greater Antilles: Lionfish are established off all islands in the Greater Antilles (Cuba [2007], Jamaica [2008], Hispaniola [Haiti and the Dominican Republic; 2008] and Puerto Rico [2009]). Lionfish are classified as established off Hispaniola due to the documentation of their spread in the Dominican Republic; however, data for Haiti is lacking.

Lesser Antilles: Currently (July 2009), the only reports of lionfish from the Leeward Islands are those from St. Croix (see above), where lionfish are not considered established. There have been no confirmed reports from Anguilla (UK), Antigua, Barbuda, Montserrat (UK), Nevis, Redonda, Saint Kitts, Saba (Netherlands), Sint Eustatuis (Netherlands), Saint Martin/Sint Maarten (France/Netherlands Antilles) or the French islands of Basse-Terre, La Désirade, Grande-Terre, Marie-Galante, Saint-Barthélemy,

Terre-de-Bas and Terre-de-Haut. However, there is an unconfirmed report from Sint Maarten from 2008. There are no reports of lionfish from the Windward Islands (Dominica, Grenada, Martinique [France], Saint Lucia and Saint Vincent and the Grenadines), Trinidad and Tobago or the Leeward Antilles (Aruba, Bonaire and Curaçao [Netherlands] and Coche, Cubagua, La Tortuga, Margarita Island and the Venezuelan Archipelago [Venezuela]). There have been two unconfirmed reports of lionfish sightings from Barbados (from February 2006 and January 2009).

Mexico, Central and South America: Lionfish are currently expanding through Mexican, Central and South American waters. They are considered established in Mexico, Honduras and Costa Rica (2009). Lionfish are not considered established in locations outside these three; however, establishment is likely imminent.

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