The bioinvasion of lionfish Pterois volitans (Linnaeus - 1758) in brazilian waters: an urgent necessity to create strategies to contain the expansion of the species in Brazil

A bioinvasão do peixe-leão Pterois volitans (Linnaeus - 1758) em águas brasileiras: uma necessidade urgente de criar estratégias para conter a expansão da espécie no Brasil

DOI: 10.55905/revconv.16n.7-036

Recebimento dos originais: 05/06/2023
Aceitação para publicação: 05/07/2023

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ABSTRACT
The lionfish Pterois volitans (Linnaeus, 1758) is considered the most well-established fish species in non-native regions around the world, causing severe environmental damage and risks for the food chain. In Brazil, the lionfish was reported for the first time in 2014 in the State of Rio de Janeiro, and currently, the P. volitans was observed in more eight States, being its high level of occurrence in the Northern region, which contains an immense biodiversity that has not been totally cataloged yet. Based on that, this study aims to ratify the occupation and permanent residence of the lionfish in the Great Amazon Reef System (GARS), which is an alert for the urgent need for developing control strategies for this invasive species in Brazil. The new specimens were collected in the State of Amapá, between 2021 and 2022, during commercial lobster fishing, using the method of “Caçoeirão”, covering between 70 and 100 meters of depth, while for the snapper was collected with the manzuá, between 78 and 102 meters of depth. In the laboratory, the individuals were measured in total length (TL) and total weight (TW). 21 specimens of P. volitans from the GARS, the TL ranged from 21.5 to 35.6 cm with an average of 29.43 cm, while the TW ranged from 150.0 to 733.0 g, with an average of 413.8 g. These adult specimens reinforce the stabilization of the lionfish, which have probably completed reproductive cycles in the region, requiring an urgent action by environmental agencies to control the invasion of the lionfish in Brazil, becoming a future environmental impact on native biodiversity.

Keywords: non-native fish, invasive lionfish, environmental risk, environmental legislation.

RESUMO
O peixe-leão Pterois volitans (Linnaeus, 1758) é considerado a espécie de peixe mais bem estabelecida em regiões não nativas em todo o mundo, causando graves danos ambientais e riscos para a cadeia alimentar. No Brasil, o peixe-leão foi relatado pela primeira vez em 2014 no Estado...
do Rio de Janeiro e, atualmente, o P. volitans foi observado em mais oito Estados, sendo seu alto nível de ocorrência na região Norte, que contém uma imensa biodiversidade que ainda não foi totalmente catalogada. Com base nisso, este estudo visa ratificar a ocupação e a residência permanente do peixe-leão no Sistema dos Grandes Recifes da Amazônia (GARS), o que é um alerta para a necessidade urgente de desenvolvimento de estratégias de controle dessa espécie invasora no Brasil. Os novos espécimes foram coletados no Estado do Amapá, entre 2021 e 2022, durante a pesca comercial da lagosta, utilizando o método da "Caçoeira", percorrendo entre 70 e 100 metros de profundidade, enquanto para o pargo foi coletado com o manzuá, entre 78 e 102 metros de profundidade. No laboratório, os indivíduos foram medidos em comprimento total (CT) e peso total (PT). Nos 21 espécimes de P. volitans do GARS, o CT variou de 21,5 a 35,6 cm, com média de 29,43 cm, enquanto o PT variou de 150,0 a 733,0 g, com média de 413,8 g. Esses espécimes adultos reforçam a estabilização do peixe-leão, que provavelmente completou os ciclos reprodutivos na região, exigindo uma ação urgente dos órgãos ambientais para controlar a invasão do peixe-leão no Brasil, tornando-se um futuro impacto ambiental na biodiversidade nativa.

**Palavras-chave:** peixes não nativos, peixe-leão invasor, risco ambiental, legislação ambiental.

1 INTRODUCTION

Around the world the process of bioinvasion is increasing due to climate changes and anthropic actions as environmental degradation, biopiracy and commercialization of living species, as widely observed in aquarium trade (Albins & Hixon, 2008; Muñoz et al., 2011; Acero et al., 2019). The transport of animals and plants by human activities to other regions, outside their original biogeographical limits, causes great impacts to the biodiversity, becoming a source of environmental fragility and bringing impacts to the ecosystem and to the local productive chain (Mooney & Cleland, 2001; Sanjuan-Muñoz et al., 2022). Currently, one of the main bioinvasive agents in coastal marine environments is the lionfish *Pterois volitans* (Linnaeus, 1758), native from the warm tropical waters of the South Pacific and Indian Ocean, including the Red Sea (Albins, 2015).

After its introduction into the Atlantic Ocean in the 1980s, lionfish first established along the Atlantic Coast of the USA from Florida (Miami) and South and North Carolina’s, subsequently spread to the Caribbean Sea and in Gulf of Mexico in 2009 (Schofield, 2009, Aguilar-Perera & Tuz-Sulub, 2010; Cintra et al., 2022a). In the following years, the species quickly became established resident on artificial and natural reefs in the region (Dahl & Patterson III, 2013). Currently, the lionfish is widely distributed on the western Atlantic coast, reported from the United States to Brazil; being in this last, occurring in Rio de Janeiro (Arraial...
do Cabo) (Ferreira et al., 2015), Pernambuco (Fernando de Noronha Archipelago) (Luiz et al., 2021), Pará (Cintra et al., 2022b, c), Amapá (Luiz et al., 2021; Cintra et al., 2022a), Rio Grande do Norte, Ceará and Piauí (Soares et al., 2022; 2023).

On the northern Brazilian coast, the presence of the Great Amazon Reef System (GARS) acts as a heterogeneous environment, composed of coral reefs, rhodoliths and gravel and muddy bottoms (Moura et al., 2015). This environment faces the pressure on the biodiversity caused by fishing activity; it becomes favorable for lionfish settlement, due to the removal of top predators and changes in the trophic chains. According to Dahl & Patterson III (2013) and Soares et al. (2023), the environmental degradation and the rapid invasion of *P. volitans* in some coastal habitats indicates the great adaptive capacity of the lionfish, as observed in the Atlantic Ocean, thus making it the most successful invasive species of marine fish in tropical environments.

The lionfish *Pterois volitans* is an invasive species with high dispersal potential, and due to the fragility of the habitat it occupies, especially in Brazil, it needs to be monitored, especially with respect to its establishment and main trophic and environmental impacts. In this context, this study aims to ratify the occupation and permanent residence of the lionfish in the Great Amazon Reef System, which serves as an alert for the urgent need to develop control strategies for this invasive species in Brazil.

### 2 MATERIAL AND METHODS

The specimens of *P. volitans* were collected in the State of Amapá (coordinates in table 1), in 2021 and 2022, during commercial fishing operations, using the method of “Caçoeira” covering the depths of 70 to 100 meters (lobster) and the method of “Manzuá” (snapper) between 78 and 102 meters of depth, (see table 1), in the Great Amazon Reef System (GARS), along the Brazilian Amazon continental shelf (Figure 1). After the samples, the individuals were kept frozen and transported to the Center for Research and Management of Fisheries Resources of the North Coast (Cepnor), where they were cataloged and identified according to Marceniuk et al. (2020), and measured (total length - TL and total weight – TW).
3 RESULTS AND DISCUSSION

21 specimens of *P. volitans* (Figure 2), being 17 in 2021 and 4 in 2022 in the State of Amapá, between the depths of 78 and 102 m. The lionfish specimens were caught in the lobster fishery (N= 1) and in snapper fishery (N= 20) (Table 1). The measures of TL ranged from 21,5 to 35,6 cm with an average of 29,43 cm, while the TW ranged from 150,0 to 733,0 g, with an average of 413,8 g (Table 1). According to Claydon et al. (2012), in the Caribbean sea, the density of lionfish was 10 times higher on reefs at 10 to 30 m of depth, when compared to coastal zones in seaweed beds and mangrove environments, up to 5 m deep, however, Cintra et al. (2022a) and Soares et al. (2022), reported the presence of the lionfish in Brazilian shallow waters, with depths ranging from 1 to 10 meters.
Studies provided by Morris-Jr. (2009) indicated the high reproductive rate of the lionfish in North and South Carolina waters and in the Bahamas; they report the high egg production (~ two millions of eggs per year), which gives lionfish the high capacity of colonization of new habitats. Some biological characteristics indicate the risk of this introduction into Brazilian waters such as: 1) the individuals can reach the sexual maturity at one year of age; 2) fifty percent of the males of lionfish were observed in sexual maturity around ~ 100 mm of total length (TL), while the females were observed in sexual maturity around ~180 mm of total length (TL); 3) the spawning occurs throughout the year in temperate and tropical regions, with a peak during the summer months (June, July and August), and wide dispersal of larvae and eggs by marine currents; 4) a generalist diet, associated with an effective anti-predatory defenses (poisonous spines) (Morris, 2012; Côté, Green, & Hixon, 2013; Cure, McIlwain, & Hixon, 2014). The specimens caught in Amapá presented TL above the L50 observed in Caribbean sea (see Table 1), indicating that they are adult individuals that are possibly reproducing in the region.

Figure 2. Observation in situ of the Lionfish *Pterois volitans* (Linnaeus, 1758) collected in the Great Amazon Reef System (GARS), State of Amapá, Brazil.

Source: Authors.
From Brazilian waters, the first report of the lionfish *P. volitans* was made in 2014 by Ferreira et al. (2015) in the State of Rio de Janeiro, indicating an imminent risk of invasion in other habitats along the Brazilian coast, which was subsequently reported in the northeastern region of Brazil by the first time by Luiz et al. (2021) and additional reports were provided by Cintra et al. (2022b), which collected adult individuals along the Great Amazon Reef System and Soares et al. (2022) reporting several specimens in different coastal habitats (~1 m of depth). As observed by Froese & Pauly (2023) and Soares et al. (2022; 2023), the lionfish inhabits shallow continental shelf regions (shallow waters) up to 200 m, on coral bottom, seagrass, rhodoliths beds, mangroves, sand and mud bottoms, and artificial substrates such as ships, and marine debris; the lionfish have solitary habits, with diurnal and nocturnal activities, individuals hide in burrows or crevices in coral reefs not exposed during the day, which remains motionless in the burrows in the capture of prey such as shrimps, crabs and little fishes as snapper in larval and juveniles forms; its main defense are the spines on its dorsal fin, connected to poison glands, which erupt when it feels threatened (Marceniuk et al., 2020).

As mitigating control measures, Morris-Jr. & Whitfield (2009), Morris-Jr. et al. (2011) and Gómez Lozano et al. (2013) indicated that the fishery and the lionfish consumption could be encouraged as the main control mechanism, providing a food source while reducing pressure on local fishery resources. In addition, it is urgent to provide environmental education for the community, as well as information to avoid accidents with the population on the beaches, which incidents with humans (fishermen and bathers) in Brazil have been reported by Haddad Junior et al. (2022). In Costa Rica, where the fish was first sighted in 2008, Sandel et al. (2015) suggested a local inter-institutional strategy developed in collaboration between agents from the environmental and fishing sectors, universities, and local communities, which includes: a) identify the potential areas for lionfish control based on their ecological and socioeconomic value, accessibility, and degree of infestation; b) coordinate lionfish removals to achieve a level where fishing pressure reduces population densities of the invasive species; c) establish a regular monitoring program on corals along the coast, coastal lagoons, marshes and mangroves; d) launch an awareness campaign and early warning system to prevent the introduction of lionfish to the Pacific coast e) improve communication between government and community, and develop participatory plans in management decision making processes, along with training and education for coordination in the control of this species with coastal communities. These strategies could
be applied in Brazil, especially at an early stage of lionfish introduction, so that the processes can be more effective in controlling the species population.

According to Brazilian normative ruling of Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis IBAMA - Nº 202, (October, 2008), the species authorized for sale in aquarium markets are: Species number (ID. 467 - *Pterois miles* (Bennett, 1828); ID. 468 - *Pterois radiata* Cuvier, 1829; ID. 469 - *Pterois sphex* Jordan & Evermann, 1903), being this normative valid until the present moment. These permissions may facilitate the transport of species outside their biogeographic boundaries, causing them to be introduced to other regions as exotics/invasive species. However, despite legislation indicating only three species within the genus *Pterois*, the most traded species is the *P. volitans* (see figure 3). Due to the lack of active measures, the commercialization of lionfish is already being done in some regions as ornamental fish (Figura 3), increasing the risk of the species spreading to new regions along the Brazilian coast, as was observed in the states of North Carolina and Florida in the United States. In Brazil, in 2022, the Ministério do Meio Ambiente Ministry of the Environment and the Instituto Chico Mendes de Conservação da Biodiversidade - ICMBio have launched a campaign to guide tourists, fishermen and divers. The campaign includes the distribution of educational brochures and is part of the “Guia estratégico para pesquisa, manejo e atividade de interpretação ambiental sobre o peixe-leão”. The Guide foresees that sighted fish should be reported and that captured fish should not be discarded, suggesting studies on the biology of the species, considering still an initial phase of invasion, without proposing specific measures to control the invasive population, such as encouraging consumption or more active management plans for the species.
It is important to investigate population density and structure, as this allows to assess the degree of infestation and population dynamics, increasing the ability to predict the potential distribution and impact of this species in the Atlantic. Robins (2010) suggested that studies should be conducted to examine the biology of this species, such as its temperature tolerance, reproduction, foraging strategies, and defense from predators. Another important aspect is to investigate the diet of lionfish to draw conclusions about the species most affected by lionfish predation and quantify its impacts on local fish communities. The diet of lionfish in the Caribbean is composed of teleost fish such as juvenile snapper and other individuals of the family Lutjanidae Gill, 1861 and additionally crustaceans, both in larval and adult stages, being found a great variety of native species in the diet of lionfish, characterizing a great environmental impact in the region, either by predation of other individuals or competition for food (Dahl & Patterson III, 2013; Sandel et al., 2015).

In the western Atlantic, lionfish have had catastrophic impacts on native fish populations, due to direct consumption of commercially important reef fish species, but most lionfish impact
in its invasion is associated with a reduction of 65% in prey biomass in the Bahamas (Albins & Hixon, 2008; Green, Akins, Maljkoviý, & Côté, 2012; Raymond, Albins, & Pusack, 2014). In Brazil, the impacts caused by lionfish have not been estimated yet in the long term, due to difficulties in sampling, few projects to raise awareness about the risks of contact with lionfish for the population, and lack of management plans for control and capture along the Brazilian coast. However, the frequent capture of adult specimens in fishing operations directed to other species may indicate that the species is resident and established in the region. Therefore, it is possible to assert that the establishment of lionfish in the traditional lobster and snapper fishing area in the northern coast of Brazil is of concern due to the impact that the invasion causes for the habitat and native biodiversity, with negative effects on fisheries production and marine food chains.
Table 1. Data on the new specimens of Lionfish *P. volitans* (Linnaeus, 1758) collected in the Great Amazon Reef System (GARS), State of Amapá, Brazil.

<table>
<thead>
<tr>
<th>Date</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Depth (m)</th>
<th>Fishery target</th>
<th>Fishing gear</th>
<th>Bottom Type</th>
<th>TW (g)</th>
<th>TL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021</td>
<td>03°40'0,12&quot;N</td>
<td>049°19'59,88&quot;W</td>
<td>100*</td>
<td>red snapper</td>
<td>Manzuá</td>
<td>sand, rocks and corals</td>
<td>282</td>
<td>27</td>
</tr>
<tr>
<td>2021</td>
<td>03°40'0,12&quot;N</td>
<td>049°19'59,88&quot;W</td>
<td>100*</td>
<td>red snapper</td>
<td>Manzuá</td>
<td>sand, rocks and corals</td>
<td>274</td>
<td>26,2</td>
</tr>
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<td>049°19'59,88&quot;W</td>
<td>100*</td>
<td>red snapper</td>
<td>Manzuá</td>
<td>sand, rocks and corals</td>
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<td>24,5</td>
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<td>048°24'0&quot;W</td>
<td>102</td>
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<td>Manzuá</td>
<td>sand, rocks and corals</td>
<td>733</td>
<td>34,7</td>
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<td>2021</td>
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<td>048°33'10,8&quot;W</td>
<td>98</td>
<td>red snapper</td>
<td>Manzuá</td>
<td>sand, rocks and corals</td>
<td>349</td>
<td>28,4</td>
</tr>
<tr>
<td>2021</td>
<td>04°43'11,28&quot;N</td>
<td>050°33'46,8&quot;W</td>
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<td>red snapper</td>
<td>Manzuá</td>
<td>sand, rocks and corals</td>
<td>670</td>
<td>35,6</td>
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<td>050°33'46,8&quot;W</td>
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<td>red snapper</td>
<td>Manzuá</td>
<td>sand, rocks and corals</td>
<td>624</td>
<td>34,8</td>
</tr>
<tr>
<td>2021</td>
<td>04°43'11,28&quot;N</td>
<td>050°33'46,8&quot;W</td>
<td>90*</td>
<td>red snapper</td>
<td>Manzuá</td>
<td>sand, rocks and corals</td>
<td>470</td>
<td>33,1</td>
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<tr>
<td>2021</td>
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<td>050°33'46,8&quot;W</td>
<td>90*</td>
<td>red snapper</td>
<td>Manzuá</td>
<td>sand, rocks and corals</td>
<td>150</td>
<td>21,5</td>
</tr>
<tr>
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<td>049°19'59,88&quot;W</td>
<td>100*</td>
<td>lobster</td>
<td>Caçoeira</td>
<td>sand, rocks and corals</td>
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<tr>
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<td>048°33'10,8&quot;W</td>
<td>90*</td>
<td>red snapper</td>
<td>Manzuá</td>
<td>sand, rocks and corals</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2022</td>
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<td>048°18'48,96&quot;W</td>
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<td>red snapper</td>
<td>Manzuá</td>
<td>sand, rocks and corals</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2022</td>
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<td>048°18'48,96&quot;W</td>
<td>100*</td>
<td>red snapper</td>
<td>Manzuá</td>
<td>sand, rocks and corals</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Depth estimated by the nautical chart isobath.

Source: Authors.

ACKNOWLEDGEMENTS

The authors would like to thank the Centro Nacional de Pesquisa e Conservação da Biodiversidade Marinha do Norte - CEPNOR / ICMBio for the support in sampels, the crew of the fishing boats that made this study available.
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