Predation on the invasive swimming crab *Charybdis hellerii* (Crustacea, Decapoda) by *Myrichthys ocellatus* (Actinoptyerygii, Ophichthidae): the first record of consumption by a native fish

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**ABSTRACT**

*Charybdis hellerii* is an invasive swimming crab widely disseminated in the western Atlantic. This species became a threat to colonized ecosystems, competing with local species for resources. The extension of distribution and increasing population size of *C. hellerii* has been associated with the scarcity of indigenous predators and cases of predation report octopuses as the main native predators. In this study, we present the first evidence that native fish can consume *C. hellerii*. 53 individuals of the goldspotted snake eel, *Myrichthys ocellatus*, were collected at seagrass and macroalgal beds in Pernambuco State, Brazil, and had their stomach contents analyzed. Three juvenile *C. hellerii* were found along with native prey. *Myrichthys ocellatus* feeds mainly on small crabs, thus *C. hellerii* individuals were consumed before reaching sexual maturity. Oppositely to octopuses and other crab predators, *M. ocellatus* is of little fishing interest and is commonly found in macroalgae beds, seagrass meadows and sandy areas near reefs. Our results suggest that a higher number of carcinophagous taxa may prey on this invasive crab and we emphasize that the conservation of these species is paramount for controlling *C. hellerii* populations in invaded areas.

Invasive alien species (IAS) are one of the worst threats to marine biodiversity worldwide [1,2]. Non-indigenous species have been increasingly reported to colonize the western Atlantic, at times with great success in establishing populations [3–5]. The introduction of IAS has become both biological and economical threats to local ecosystems; the colonization by the lionfish *Pterois volitans* (Linnaeus, 1758) has been acknowledged as the most deleterious invasion to Caribbean systems [6,7]. While lionfish has been recently recorded on the Brazilian coast [8,9], the IAS with most detrimental effects in Brazil are benthic: *Isognomon bicolor* (C.B. Adams, 1845) (a Caribbean bivalve), *Tubastraea coccinea* Lesson, 1830, *Tubastraea tagusensis* Wells, 1982, *Chromonephthea braziliensis* van Oooven, 2005 (Indo-Pacific corals) and *Charybdis hellerii* (A. Milne-Edwards, 1867) (an Indo-Pacific swimming crab) [10–12].

*Charybdis hellerii* has colonized the Atlantic Ocean through the Mediterranean Sea with the opening of the Suez Canal, reaching the western Atlantic by the end of the 80’s [13]. This species spread along the Caribbean in the following years, probably transported by ballast water and local currents [14,15]. The rapid growth, continuous reproduction, along with the generalized habitat and diet requirements of *C. hellerii*, allowed a successful establishment and spread of this IAS, which is now found in virtually the entire Brazilian coast, from Pará to Santa Catarina states [13,16].

Local impacts caused by *C. hellerii* are still under-reported; however, available literature indicates potential economic and biological effects [10]. In Twin Cays, Belize, this crab is possibly displacing other decapods previously found in higher abundances at the area (e.g. spider crabs (*Mithrax* spp.), swimming crabs (*Callinectes* spp.) and spiny lobsters (*Panulirus* spp.)) [17]. In some Brazilian states (e.g. São Paulo and Santa Catarina), *C. hellerii* has outnumbered local crab populations, competing for resources with native species [4,16]. The use of this invasive crab in local fisheries is minimal; for example, in Venezuela (Falcón State), *C. hellerii* represented 5% of the captures in crab artisanal fisheries in 2003–2004 [18]. Moreover, *C. hellerii* was also identified as a potential host for the white spot disease virus, which causes high mortality in shrimp [10].

In spite of the complexity of processes that underlie biological invasions, IAS success can be linked to reduced population control by predators (i.e. the enemy release hypothesis) [19–21]. In fact, the instances of predation on *C. hellerii* by indigenous species are very limited and highlight octopuses as the most common consumers [22,23]. Here, we present the first report indicating that fish may act as predators of this invasive species. Predation on *C. hellerii* by
native fish was revealed by the analysis of stomach contents of the goldspotted snake eel, *Myrichthys ocellatus* (Lesueur, 1825). This species is found from Bermuda and South Florida, in the Caribbean, to Santa Catarina, in Brazil [24,25].

Samples were collected on the beaches of Catuama (7°37′40.7 “S; 34°48′19.9″ W) and Tamandaré (08°45′35″S; 35°06′17″W), located on the Northern and Southern coasts, respectively, of the State of Pernambuco, Brazil (Figure 1). The Catuama beach is influenced by the Itamaracá estuarine complex and comprises the largest seagrass meadows in the region where individuals of *M. ocellatus* were captured. Tamandaré, on the other hand, is part of the most extensive marine protected area in the Brazilian coast, the Costa dos Corais Marine Protected Area. The Tamandaré reef complex includes one of the largest fringing reef formations in the South Atlantic. In this site, *M. ocellatus* was captured at the macroalgal beds adjacent to shallow reefs (also see study location in [26]). The goldspotted eel is very common in the study area [27,28], but there are no records of *C. hellerii* presence on both sites sampled prior to this study.

Individuals were captured during free dives performed between August and December 2019, on low tides at a maximum depth of 2 m, using hand nets (~40 cm diameter, 1.5 cm mesh). A total of 53 individuals were collected, 25 being captured in Catuama and 28 in Tamandaré, with sizes ranging from 33.5 to 66 cm in total length, with an average of 46.6 cm. After collection, specimens were fixed in a 4% formaldehyde solution. In the laboratory, stomach contents were removed on a petri dish and identified under stereo-microscope (40x magnification). Each individual prey was measured with a digital caliper (0.1 mm accuracy) and preserved in 70% ethyl alcohol.

Three individuals of *Charybdis hellerii* were found in the stomach contents of *Myrichthys ocellatus* (Figure 2). Specimens found were sexually immature; two males and a female measuring 11, 12 and 19 mm in carapace width (CW), respectively. The female was consumed by an individual of *M. ocellatus* with 47 cm of total length (TL) and one of the males was found as a prey of a fish with 39 cm TL, both collected in Catuama beach. The male with 11 mm CW was found within stomach contents of a 52 cm TL goldspotted eel sampled in Tamandaré.

*Myrichthys ocellatus* preys mainly on mobile invertebrates, especially crabs of the families Portunidae, Xanthidae and Majidae [27–29]. During our stomach contents analysis, we found that the bulk of *M. ocellatus* diet is composed by these native crab species (e.g., *Callinectes* spp., *Pithe* sp., *Epialtus* sp.), also registering the ingestion of mollusks, isopods and shrimps to a lesser extent.

This is the first record of a native fish using *C. hellerii* as prey, suggesting that a higher number of carco-phagous taxa may feed on this invasive crab as well. Other species have been suggested as potential

Figure 1. The goldspotted eel *Myrichthys ocellatus*, a novel predator of *Charybdis hellerii* (a). Location of collection sites, Catuama and Tamandaré beaches in Pernambuco, northeastern Brazil (b).
predators of *C. hellerii*, such as larger native Portunidae crabs (e.g. *Callinectes ornatus* Ordway, 1863) and reef-associated groupers (e.g., *Mycteroperca* spp. and *Epinephelus* spp.) [22,28], but empirical evidence is still lacking.

Oppositely to the predation performed by octopuses or larger fish, which target larger prey [23], *M. ocellatus* predates preferentially on small crabs, well below the size of first maturity for *C. hellerii*, which is approximately 37 mm CW for females [29–32]. Bearing in mind that each female of *C. hellerii* can produce from 22,500 to 3,200,000 eggs per reproductive event [14,33], the predation of this exotic crab before breeding can represent an effective way of local control of its spread [23].

Additionally, groupers, crabs and octopuses are of high fishing interest and their populations are in decline [34–39], while snail eels are of little economic value and are not fished at all [40]. One of our study sites, Catuama beach, is heavily targeted by fishing and show highly depleted fish communities when compared to other seagrass meadows in the region [41]. Yet, *M. ocellatus* seems to have high abundance in the area, and may contribute in preventing the local establishment of *C. hellerii*. Indeed, seagrass-associated macrofauna surveys in this study site does not show indications of established populations; in a previous survey performed in 2017 by our study group, 4,500 invertebrates were sampled and not a single individual of *C. hellerii* was captured [42].

The goldspotted eel is a crab predator found in various habitats, such as seagrass meadows, macroalgal beds, rocky shores and coral reefs [26–28]. It is also a conspicuous member of the ichthyofauna along a large extent of the area colonized by *C. hellerii* in the western Atlantic [43]. We hypothesize that *M. ocellatus*, along with other carcinophagous fish, may play an important role in the dynamics of *C. hellerii* invasion, to be evaluated in further studies. Our results emphasize the importance of the conservation of local carcinophagous species, given their potential role in the control of populations of this invasive crab.

**Acknowledgments**

We thank colleagues from the Laboratório de Pesquisa em Ichtiologia e Ecologia de Recifes – LabPIER, Silva MC, Xavier TF and Silva CVC for their assistance in fieldwork.

**Disclosure statement**

No potential conflict of interest was reported by the author(s).

**Funding**

AOA thanks the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the Research Scholarship Support (PQ # 304235/2019-9).

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