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The tropical *Octopus insularis* (Mollusca, Octopodidae): a natural enemy of the exotic invasive swimming crab *Charybdis hellerii* (Crustacea, Portunidae)

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Abstract. *Charybdis hellerii* is currently found all over the Brazilian coast, being a threat to native crustaceans, due to competition. The present study shows a native predator as its natural enemy, possibly controlling *C. hellerii* population since juveniles are preyed the most.

Key words: Bioinvasion, predation, enemy release hypothesis, sandstone reef.

Resumo. O polvo tropical *Octopus insularis* (Mollusca, Octopodidae): um inimigo natural do siri exótico invasor *Charybdis hellerii* (Crustacea, Portunidae). *Charybdis hellerii* atualmente é encontrado em toda a costa brasileira, sendo uma ameaça aos crustáceos nativos devido a competição. A presente nota mostra um predador nativo como seu inimigo natural, possivelmente afetando sua população, uma vez que os juvenis de *C. hellerii* são os mais predados.

Palavras-chave: Bioinvasão, predação, hipótese do relaxamento da pressão por inimigos, recife de arenito.

Bioinvasion is considered one of the greatest threats to biodiversity (Molnar et al., 2008). Although human activity has been introducing marine species for centuries, the number of introduced species has increased considerably in recent decades (Ruiz et al., 1997; Seebens et al., 2013). Generally, only part of the introduced species successfully colonizes the new environment. Those that do adapt, however, have a negative effect not only on the ecosystem, but also on the industry and economy (Carlton, 2002), for example the *Phylloxera* insect that destroyed 40% of French wineries in the 18th century (Banerjee et al., 2010); in public health the H1N1 and H5N1 influenza strains that were spread throughout the world through air travel (Mangili & Gendreau, 2005).

However, natural enemies as predators and parasites, can interfere in the invasion process. Several studies have shown predators limits local population size, geographical range and habitat use of invaders (Baltz & Moyle, 1993; Byers 2002; DeRivera et al., 2005; Ruesink 2007). For example, Ward-Fear et al. (2010) used native ants to control an introduced toad population and Baltz & Moyle (1993) concluded that native predator fish may prevent the nonindigenous fish species from invading California streams in United States. Yet not all predators incorporate the new species into their diet. Even a generalist predator can avoid an invasive potential prey, despite its abundance (see Llewelyn et al., 2010 and Sih et al., 2010).

The exotic swimming crab *Charybdis hellerii* (A. Milne-Edwards, 1867), native to the Indo-Pacific, is a well-established specie in the Brazilian coast. This crustacean was first found in the Western Atlantic Ocean in the 1980s (Campos & Türkay, 1989) and spread to Brazil in 1995 (Tavares & Mendonça, 1996), where it is found in estuaries and

beaches along the entire Brazilian coast. *C. hellerii* has features that enables it to colonize new habitats successfully, such as a long larval stage - 44 days -, and continuous reproduction throughout the year (Mantelatto & Garcia, 2001). The number of reported and potential impacts of this attacker is extensive. In some regions in Brazil, it is one of the most abundant species among the native Portunidae and has a generalist diet, preying on other crustaceans (Sant'anna et al., 2015). Since it is a non-commercial species, *C. hellerii* is also a potential competitor of the species of *Callinectes* (Tavares & Mendonça Jr., 2004), which are the targets of artisanal fisheries in many parts of the Brazilian coast. To date, there are few records of the natural predators of this crustacean in Brazil: Mantellato & Garcia (2001) suggest that other larger Portunidae (e.g. *Callinectes ornatus*) may prey on *C. hellerii*. Sampaio & Rosa (2006) recorded the predation of *Octopus* cf. *vulgaris* on *C. hellerii*, although this record was based on a few observations (five) and raises questions concerning the frequency of this predation.

Octopuses are reported as the main predators of benthic invertebrates (Ambrose, 1986). In northern and northeastern Brazil, *Octopus insularis* is the dominant species of octopus in shallow waters and it feeds mostly on crustaceans (Leite et al., 2009a; 2009b). This fact can attribute to this species the condition of natural predator of *C. hellerii*, controlling its population. The aim of this work was to verify whether *O. insularis* preys on *C. hellerii* in an intertidal environment where the exotic crab is mostly concentrated (Sant'Anna et al., 2012), the frequency of this predation, and whether there is a relationship between the size of the predator and the size of its prey. The samples were collected during the daytime spring low tides in the intertidal strip of Ponta do Mel beach, Rio Grande do Norte State, Northeastern Brazil (4° 57 'S; 36° 53' W). An abrasion platform of consolidated sandstone measuring 23,761 m² covers this intertidal strip to the sublittoral zone and it creates an environment of high algal cover and tide pools, where *Charibdys hellerii* is easily observable (Fig. 1a). This area also has plots of sandy substrate.

The sampling period was April 2012 to July 2016, resulting in 22 samples. The presence of *C. hellerii* in octopuses' diet was determined using two methods: i) instantaneous daytime observation of animals feeding outside the dens (see Villegas et al., 2014) (Fig. 1b) and ii) animals inside the dens with remains of recent prey within a radius of up to 0.5 m from the den (Fig. 1c.) (Leite et al., 2009a). The size of the animals was determined by measuring carapace width (CW) for *C. hellerii* and the mantle length (ML) for *O. insularis*. Mantle length was categorized into two sizes: M (ML 51 to 99), and L (ML > 100 mm). The normality of data was verified using the Shapiro-Wilk test. We applied Pearson's correlation coefficient to verify the correlation between the predator vs. prey size and an ANOVA to identify differences in the CW measurements between the octopus size categories. All statistical analyses were conducted using R Studio software (RStudio Team, 2015).

Sampling resulted in 69 octopuses and 20 specimens of *C. hellerii*, which was the third most consumed species and the crustacean with the highest occurrence (25.45%) in the sample (Table I).

Carapace width (CW) ranged from 13.04 to 52.76 mm, with mean of 34.09 ± 10.75 mm, and did not correlate with the size of the octopus ($t = 0.0196$, $df = 16$, p-value = 0.9846). However, average CW was statistically different between the categories of octopus size "G" (37.71 ± 1.23mm) and "M" (25.02 ± 12.74 mm) (ANOVA: $F = 6.528$; p-value = 0.01). These data conform to the general foraging pattern, in which predators seek larger prey as they get larger (Schoener, 1971). *Charybdis hellerii* is preyed upon from the smaller sizes (34.09 ± 10.75 mm) to the size of first sexual maturity, which occurs around 35 mm in females (Mantelatto & Dias, 1999).

Considering that each female of the exotic invader crab can produce from 22,500 to 3,200,000 eggs per reproductive event, depending on the size of the individual (Siddiqui & Ahmed, 1992; Lemaitre, 1995), preying upon the crab can be an effective way of controlling the population since the animal is removed before breeding. *O. insularis* is an opportunistic predator and a time minimizer with a preference for crustaceans (Leite et al., 2009) so it is expected that *O. insularis* preys the exotic swimming crab where they co-occur. However, none of the five studies published, so far, about this predator's diet in Brazilian coast and islands found *C. hellerii* among its preys (Batista & Leite, 2016; Bouth et al., 2011; Leite et al., 2009a; Leite et al., 2016).

Invasive species are expected to have few natural enemies in a new environment. According to Enemy Release Hypothesis (ERH), this is one of the bottlenecks of bioinvasion, regardless of the impact the species can cause (Mitchel & Power, 2003).

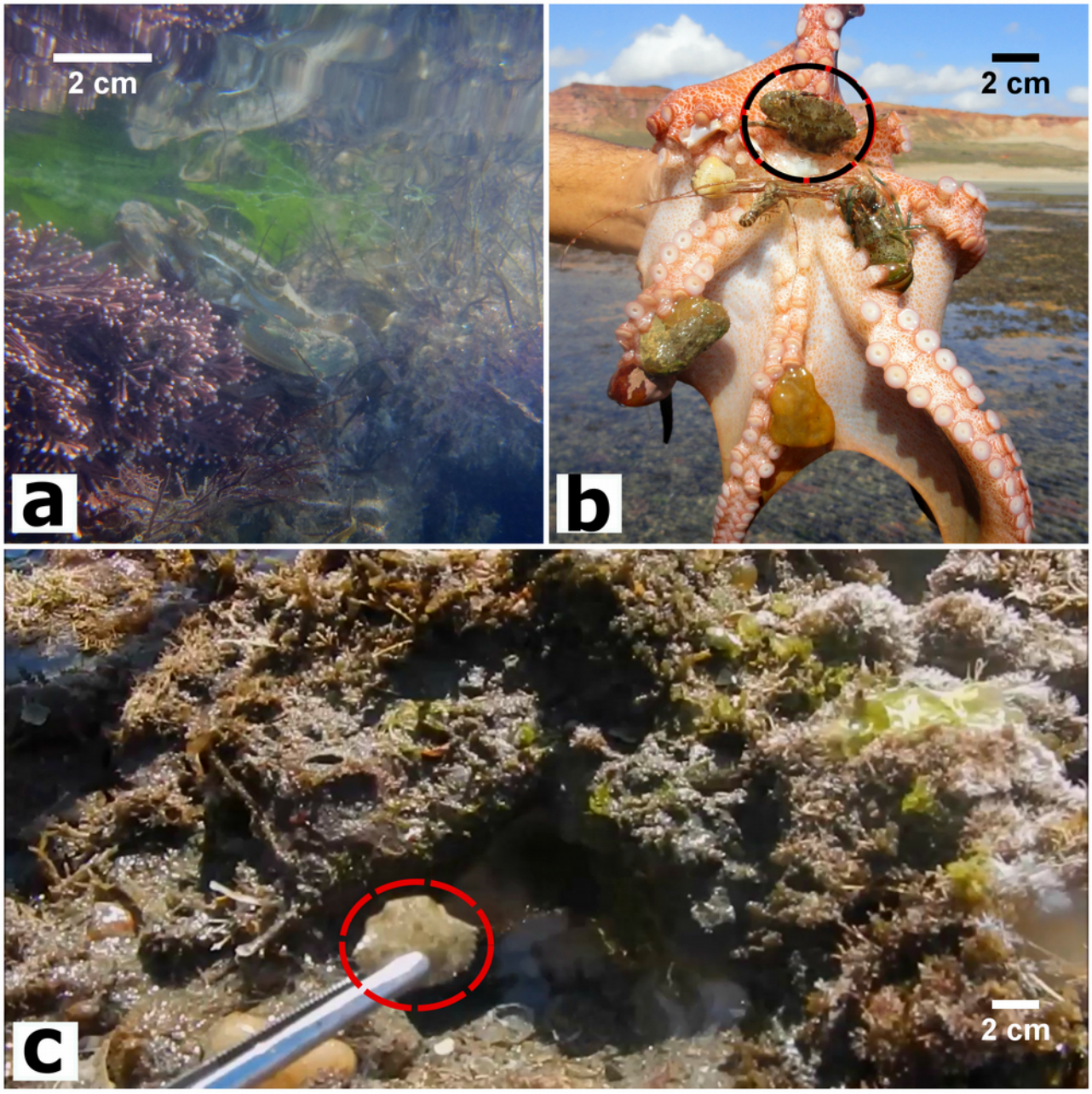

Figure 1.- Photos of the animals in their natural environment, during sampling: A - *Charybdis hellerii* (A. Milne-Edwards, 1867) in a tidal pool at low tide; B - *C. hellerii* (red/ black circles) after being captured by *Octopus insularis* Leite & Haimovici, 2008, along with other species of prey (direct observation method); C - Carapace of *C. hellerii* during removal from the octopus den (prey remains method), note the octopus occupying it, in the background.

Table I. List of the three main prey found in the diet of *Octopus insularis* Leite & Hamovici, 2008 in Ponta do Mel beach - RN. *sample number of 69 octopuses.

Species	Occurrence*	Quantity
Chione cancellata	41	162
Semele proficua	13	24
Charybdis hellerii	14	20

Therefore, successful colonization is directly related not only to the biology of invasive species and the new environment conditions, but also to predation. Native predators can regulate the long-term dynamics of invasive species (Parker et al., 2006, Carlsson et al., 2009). This seems to be the case of *C. hellerii* in the study area, since it is one of the main items found in the diet of the native octopus.

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