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Short Communication

The invasive brittle star *Ophiothela mirabilis* Verrill, 1867 (Echinodermata, Ophiuroidea) in the southwestern Atlantic: filling gaps of distribution, with comments on an octocoral host

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ABSTRACT. *Ophiothela mirabilis* is native to the Pacific Ocean and has recently invaded the Caribbean and the southwestern Atlantic. In this study, using SCUBA diving techniques, we observed specimens of the invasive *O. mirabilis* in association with an octocoral host (*Leptogorgia punicea*) at the equatorial margin in the southwestern Atlantic (03°32′S, 38°47′W). We filled a gap of more than ~1,500 km between the Amazon reefs and the coast of Pernambuco State. The results indicate that *O. mirabilis* has invaded ~6,700 km of coastline in the southwestern Atlantic in the last 17 years. Moreover, our results support the hypothesis that the consistent color pattern of specimens from Brazil, French Guiana, Saint Vincent, and Tobago indicates the existence of a single lineage proliferating by asexual reproduction. Because the South Atlantic is the most recent of the oceans, as well as a hotspot for tropical biodiversity, much more information on invertebrate bioinvasions in this region is needed.

Keywords: Artificial reef, octocoral, benthos, ecosystem, seaport, Brazil.

Invasive species represent a major threat to marine biodiversity (Mooney & Cleland, 2001; Paul & Kar, 2016). Marine benthic ecosystems often display a high level of three-dimensional complexity and biodiversity dominated by sessile animals. Rossi (2013) referred to these animal-dominated ecosystems as marine animal forests, including octocorals, considered as eco-engineering species based on their ability to modify seafloor habitats. As a functional forest, octocorals provide feeding substrate and habitat for a diversified biota, including native and invasive species (Sheehy & Vik, 2010; Sánchez, 2016; Soares *et al*., 2017).

The brittle star *Ophiothela mirabilis* Verrill, 1867 is native to the Pacific Ocean (Hendler & Brugneaux, 2013), but has recently invaded the Caribbean and the southwestern Atlantic (Hendler *et al*., 2012). The recent report of *O. mirabilis* from reefs off the mouth of the Amazon (Moura *et al*., 2016) is more a striking example of the lack of faunal monitoring and the urgent need for studies on geographical expansion and the impact of invasive species on marine ecosystems.

In this study, we observed specimens of the invasive *O. mirabilis* in association with an octocoral host (Fig. 1a) at Ceará State in the southwestern Atlantic (Fig. 1b). With this record, we are updating the knowledge of the distribution of the species.

The study area was an artificial reef structure off Pecém (03°32'S, 38°47'W), a seaport in the State of Ceará, northern region of Brazilian reefs (Fig. 1b), 56 km west of Fortaleza (the State capital). Operating since 2002, the port of Pecém is in a favorable geographic location, with easy access to Africa and Europe. The offshore terminal is a technologically advanced structure connected to the shore facilities by a 1 km long bridge (Cearáportos, 2007).

The specimens of *O. mirabilis* and *Leptogorgia punicea* (Milne-Edwards & Haime, 1857) were deposited in the Echinodermata, and Cnidaria collections at the Laboratório de Invertebrados Marinhos do Ceará (LIMCe) of the Universidade Federal do Ceará (UFC) under the vouchers #ECHINODERMATA-398 and #CNIDARIA-049, respectively. The specimens of *O. mirabilis* and *L. punicea* were preserved either in ethanol 70%.

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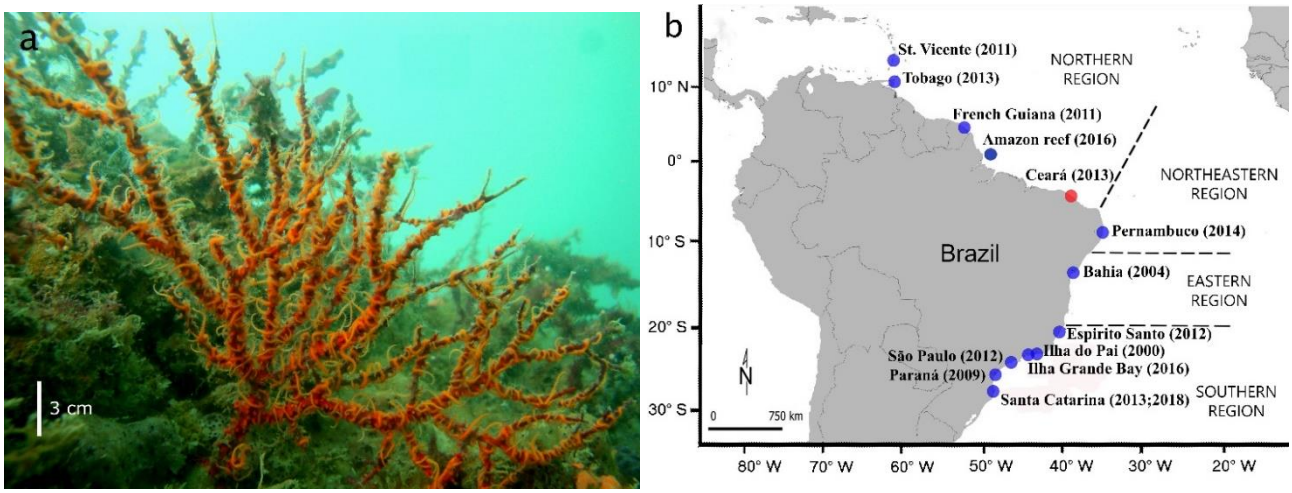

Figure 1. Distribution of *Ophiothela mirabilis* in the southwestern Atlantic. a) Dense colonization of the octocoral *Leptogorgia punicea* by *O. mirabilis* at 5 m depth, off Ceará coast, b) chronology reports of *O. mirabilis* in the southwestern Atlantic. Map based on data published by Leão *et al.* (2016) and Mantelatto *et al*. (2016).

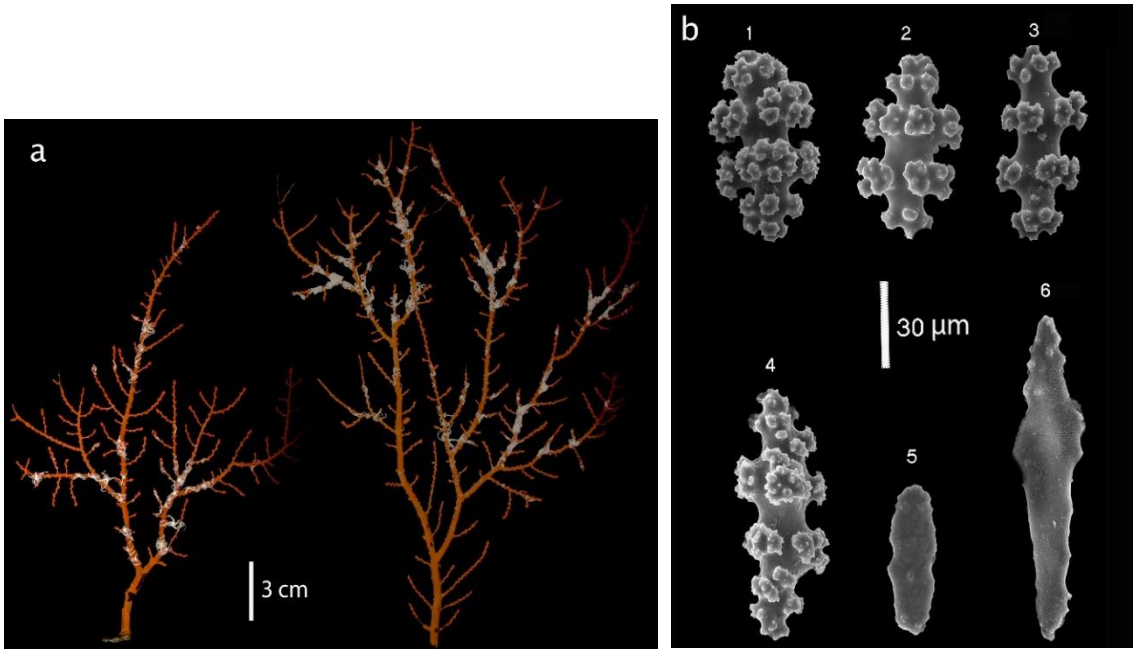

Figure 2. Colonies and scanning electron microscope images of sclerites of the octocoral *Leptogorgia punicea* (#CNIDARIA-049). a) Colonies openly pinnate, almost always flat, b) spindles from coenenchyme (1-4) and flat anthocodial rods (5-6).

Our survey revealed the presence of the ophiuroid *Ophiothela mirabilis* off the coast of Ceará, in association with the octocoral *Leptogorgia punicea* (Fig. 2a). The first report of *O. mirabilis* from Ceará and the second occurrence observed in association with *L. punicea* in this tropical coast. *Ophiothela mirabilis* is known to associate with several species of octocorals, including three species of *Leptogorgia*, like *L. punicea* (Hendler *et al*., 2012).

More recently, Cordeiro *et al*. (2015) observed a vast diversity of octocorals (26 species) on a mesophotic reef off the mouth of the Amazon, but in that area, *O. mirabilis* was only associated with *Leptogorgia miniata* (Milne-Edwards & Haime, 1857)

Ophiotela mirabilis (Figs. 3a-3b) is a small ophiuroid measuring up to 3 mm in diameter. The species has six arms which may be three times longer than the disc diameter. The aboral surface of the disc is covered by

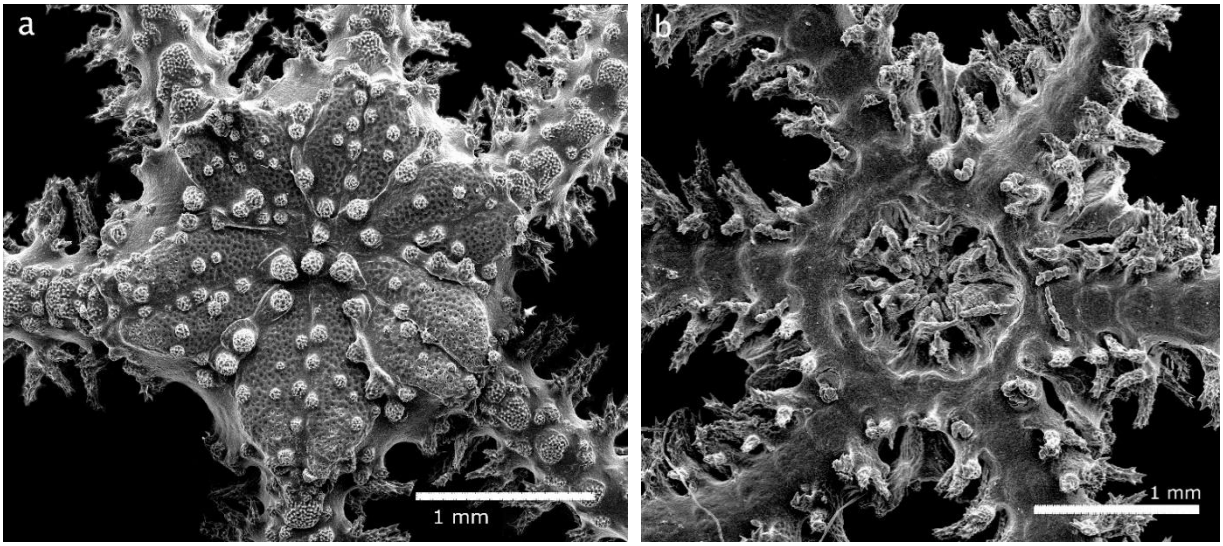

Figure 3. Scanning Electron Microscope (SEM) images of *Ophiothela mirabilis* Verrill, 1867 (#ECHINODERMATA-398). a) Aboral surface of the disc, b) oral surface of the disc. Scale bars = 1 mm.

skin with rounded granules of uneven size and distribution. This skin with these rounded granules covers the aboral surface of the arms and the radial shields of the disc. The radial shields of the disc are large and possess oval shape. Exhibit five tapering arm spines. These spines are thorny; two of them on the lower side present well-developed hooks at the tip. The spines on the arms are short and blunt. The jaws are studded with a cluster of dental papillae. The yellow-orange coloring is brighter on the aboral surface (Moura *et al*., 2016).

Mantelatto *et al.* (2016) recorded the occurrence of *O. mirabilis* on *Leptogorgia setacea* (Pallas, 1766), *L. punicea*, *Heterogorgia uatumani* Barreira & Castro, 1990 and *Carijoa riisei* (Duchassaing & Michelotti, 1860).

Mantelatto *et al.* (2016) identified 29 host taxa/functional groups used by *O. mirabilis* in the southwestern Atlantic. The low host specificity of this ophiuroid has probably favored its propagation in this region. However, little is known about the ecological effects of *O. mirabilis* on native eco-engineering species. The species is commonly associated with benthic suspension feeders, such as sponges, scleractinian corals, zoanthids, ascidians, bryozoans and, especially, octocorals (Mantelatto *et al.*, 2016; Moura *et al*., 2016).

Ophiothela mirabilis attaches to octocorals, rolling their arms around the gorgonians with the aid of hooked spines (Granja-Fernández *et al*., 2014). According to Hendler *et al.* (2012) and Mantelatto *et al.* (2016), *O. mirabilis* tends to attach to octocorals near the polyps; our observation supported this affirmation. We hypothesized that the preference and high density of *O. mirabilis* near the polyps might compromise the host's ability to obtain nutrients. However, further studies on trophic ecology using modern techniques (*e.g.*, stable isotopes) are necessary to clarify the nature of the relationship.

The present study is the first record of *O. mirabilis* to a little-studied area (the coast of Ceará) in the southwestern Atlantic (Fig. 1b). Environmental monitoring off the port of Pecém between 2004 and 2013 showed no apparent signs of *O. mirabilis*, suggesting the invasion and colonization are recent (Anonymous, 2013). The presence of *O. mirabilis* near ports suggests the introduction of the species may be associated with ballast water (*i.e.*, larvae transport) or hull-fouling (Hendler *et al.*, 2012). The transport of *O. mirabilis* on ships' hulls and by rafting to the Atlantic can be explained by the small size of the species, resistance to dislodgement and its association with diverse sessile organisms (Hendler & Brugneaux, 2013).

The native Pacific populations of *O. mirabilis* are variously colored (purple rosaceous, creamy, burgundy and yellow) (Granja-Fernández *et al*., 2014). According to these authors, the variation in color may be explained by color differences between the octocorals from which the specimens were collected. In contrast, the specimens of *O. mirabilis* observed off Ceará are yellow-orange, matching reports from reefs off the Amazon, Bahia, Espírito Santo, Rio de Janeiro, São Paulo and Paraná (Hendler *et al.*, 2012; Mantelatto *et al.*, 2016; Moura *et al*., 2016). Interestingly, almost all specimens of *O.*

mirabilis collected in the southwestern Atlantic and the Caribbean display the same yellow-orange color. Hendler & Brugneaux (2013) suggested that the consistent color pattern of specimens from Brazil, French Guiana, Saint Vincent, and Tobago suggests the existence of a single lineage proliferating by asexual reproduction (fission) following a one-time introduction into the Atlantic (Hendler *et al*., 2012). Our results from Ceará support this hypothesis.

In this study, we filled a gap of more than 1,500 kilometers between the Amazon reefs and the coast of Pernambuco State (Fig. 1b). Pooling our records with the data from the literature shows that *O. mirabilis* has invaded ~6,700 km of coastline in the southwestern Atlantic. *Ophiothela mirabilis* was first reported from Brazil in 2000, based on specimens observed in Rio de Janeiro (Hendler *et al.,* 2012). Subsequently, the species was recorded from Bahia (in 2004), Paraná (in 2009), Espírito Santo and São Paulo (in 2012), mouth of Amazonas River (in 2016), Pernambuco (in 2014) and Santa Catarina (in 2013 and 2018) (Hendler *et al.*, 2012; Mantelatto *et al*., 2016; Moura *et al.,* 2016; Lawley *et al.,* 2018). Thus, available data indicate an increase in distribution over the past 17 years.

Our record is in the northern region of Brazilian reefs (NBR) (Fig. 1b). Restricted to the Brazilian coastline, the tropical southwestern Atlantic may be divided into four geographic regions: north, northeast, east, and southeast (Leão *et al*., 2016). The coral reefs in the northern region (NBR) are the least studied along the Brazilian coast (Soares *et al*., 2016). Stretching between the Amazon River and the Cape of São Roque (0º30'S to 5º29'S), it represents a transition between the Caribbean and Brazilian reefs. One of the most important oceanographic features of the region is the northwestward-flowing North Brazil Current (NBC) (Leão *et al*., 2016).

The NBR (Fig. 1b) is the least studied region along the Brazilian coast, representing a knowledge gap regarding the transition from the Caribbean to Brazilian reefs (Leão *et al.,* 2016). As such, this region still holds poorly studied marine animal forests, such as subtidal sandstone reefs (Soares *et al.,* 2016) and the extensive and mesophotic reefs off the Amazon River (Cordeiro *et al.,* 2015; Moura *et al.,* 2016). Moura *et al*. (2016) recently reported *O. mirabilis* from reefs off the Amazon Estuary, suggesting invasive species can reach the southwestern Atlantic from the Caribbean through the countercurrent dispersal route. Moreover, with manmade structures (ports, oil and gas platforms) as stepping stones, the northwestward-flowing NBC may have connected these habitats and facilitated the dispersion of *O. mirabilis* into the shallow and mesophotic ecosystems in NBR. Hendler & Brugneaux (2013) proposed the dispersion in the Atlantic by natural transportation (*e.g.*, ocean currents).

In conclusion, biological invasions are likely to have a negative impact on native eco-engineering species such as octocorals. Because the south Atlantic is the most recent of the oceans, as well as a hotspot for tropical biodiversity, much more information on invertebrate bioinvasions in this region is needed (Rocha *et al*., 2013; Castro *et al*., 2017). Urgent efforts should be made to identify the positive or negative aspects of the interaction between *O. mirabilis* and native octocorals, along with their potential effects on marine ecosystems.

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