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First record of *Amorphinopsis atlantica* (Porifera: Demospongiae: Halicondriidae) in the Paraguaçu River estuary: Is its presence an invasion or an adaptation to changing environmental conditions?

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Abstract

Herein, we describe the first-ever identification of *Amorphinopsis atlantica* in the Iguape Bay (Bahia, Brazil). The bay, where fish and shellfish harvesting has been practiced for centuries, is part of the Paraguaçu River estuary, the main tributary of Todos-os-Santos Bay. Massive encrusting specimens of sponge species growing on three different types of substrates were collected manually in the intertidal zone of a mangrove in an estuary; despite being initially described in Brazilian subtropical coastal waters. There are records for *A. atlantica* in the southeastern states of Rio de Janeiro, São Paulo, and northeastern states of Pernambuco, Paraíba (Brazil), Falcón (Venezuela), Campeche and Vera Cruz (Mexico), in the department of Córdoba (Colombia), in the Hidden Creek district (Belize) and the Atlantic coast of Costa Rica. In the collection area, the construction of a dam in the tidal river and the subsequent hydroelectric power have changed the estuary dynamics to a threshold condition expected to be tolerated by new colonizers organisms. In this unpredictable scenario, *Amorphinopsis atlantica* has found a new habitat for more than 15 years. Local people have alleged that the sponge may cause recurring skin rashes, but this has not yet been confirmed. Monitoring and study on the distribution and abundance of the species and a medical survey may clarify the role of the sponge on the skin dermatitis complained by the local population.

Key words: Marine sponge, first record, organism, estuary, tropical waters

Introduction

The genus *Amorphinopsis* Carter, 1887, which falls under the family Halichondriidae with 14 valid genera, is currently represented by 18 valid species (de Voogd *et al*. 2022). The external morphology of this genus varies from encrusting to massive forms, occasionally with irregular branches extending from a massive base, consisting of differentiated spicules, including larger oxeas and derived forms, smaller oxeas and small styles, concentrated at the surface (Erpenbeck & van Soest 2002).

The species *Amorphinopsis atlantica* Carvalho, Hajdu, Mothes & van Soest, 2004 was first described in southeastern Brazil , and has since been recorded in the northeastern states of Paraíba and Pernambuco (Santos *et al*. 2018), La Restinga Lagoon (Falcón, Venezuela) (Guerra-Castro *et al.* 2016), Cispetá Bay (Córdoba, Colombia)

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(Quirós-Rodríguez 2015), Hidden Creek (Stann Creek, Belize) (Diaz & Ruetzler 2009), Laguna de Terminos (Campeche, Mexico) (Briceño-Vera *et al*. 2021), Tampamachoco Lagoon (Vera Cruz, Mexico) (de la Cruz-Francisco *et al*. 2019) and Costa Rica (Cortés *et al*. 2009). This paper presents the first formal record of *A. atlantica* in Bahia (Brazil) following indications by fishermen of recently arrived species in the Iguape Bay, in the Paraguaçu River estuary (Fig. 1).

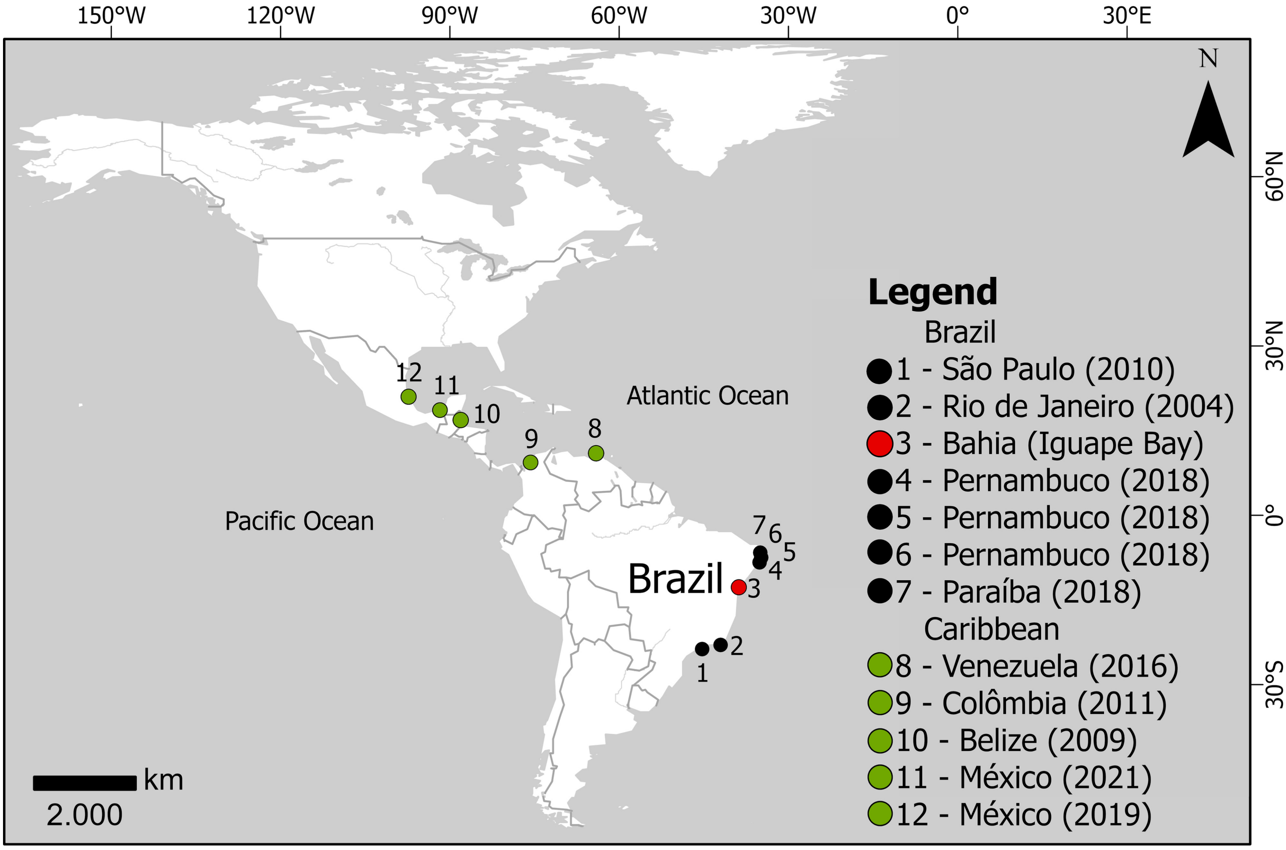

FIGURE 1. Occurence of *Amorphinopsis atlantica* in Central and South American Atlantic Ocean.

Materials and methods

Study area. Sampling was carried out in Iguape Bay (12°40′26″ S; 38°51′24″ W) (Fig. 2), located in the Paraguaçu River estuary, west of Todos-os-Santos Bay in Bahia State, Brazil (Genz 2006). The estuary is composed of three segments: a 16-km-long upper stretch of the tidal river, blocked by the Pedra do Cavalo Dam; Iguape Bay, which has an area of 76.1 km^2 and is formed by one of the steps of a fault zone in the western side of the graben rift; and the 18-km-long Paraguaçu Channel that connects this small bay to Todos-os-Santos Bay (Genz *et al* 2008). Iguape Bay and the lower part of the Paraguaçu River estuary are used as a fish and shellfish harvesting, providing a livelihood for approximately 5,000 families in the area.

Sampling. Specimens (n=3) were collected manually in the estuary's intertidal zone during the low spring tide and were selected through direct observation. The sponges were attached to the roots of mangrove trees, rigid substrates on the mangrove sediments, and fish trap stakes made from mangrove branches. The specimens were placed in individual plastic bags and preserved in 80% ethanol (Hajdu *et al.* 2011). All specimens have been deposited in the Porifera Collection at the Museu de História Natural da Bahia (MHNBA).

Analysis. Light microscopy and scanning electron microscopy (SEM) were used for the morphological analysis of the sponge structures, as described by Hajdu *et al.* (2011). The skeleton and spicules of the sponges were observed under an Olympus CX21 light microscope. Micrometries (length / width) included 30 spicules of each category of spicule. SEM images of the spicule morphology were obtained using a JEOL JSM-6390LV scanning electron microscope. Taxonomic identification of the *A. atlantica* specimens was carried out according to the methods described by Carvalho *et al.* (2004) and Santos *et al.* (2018).

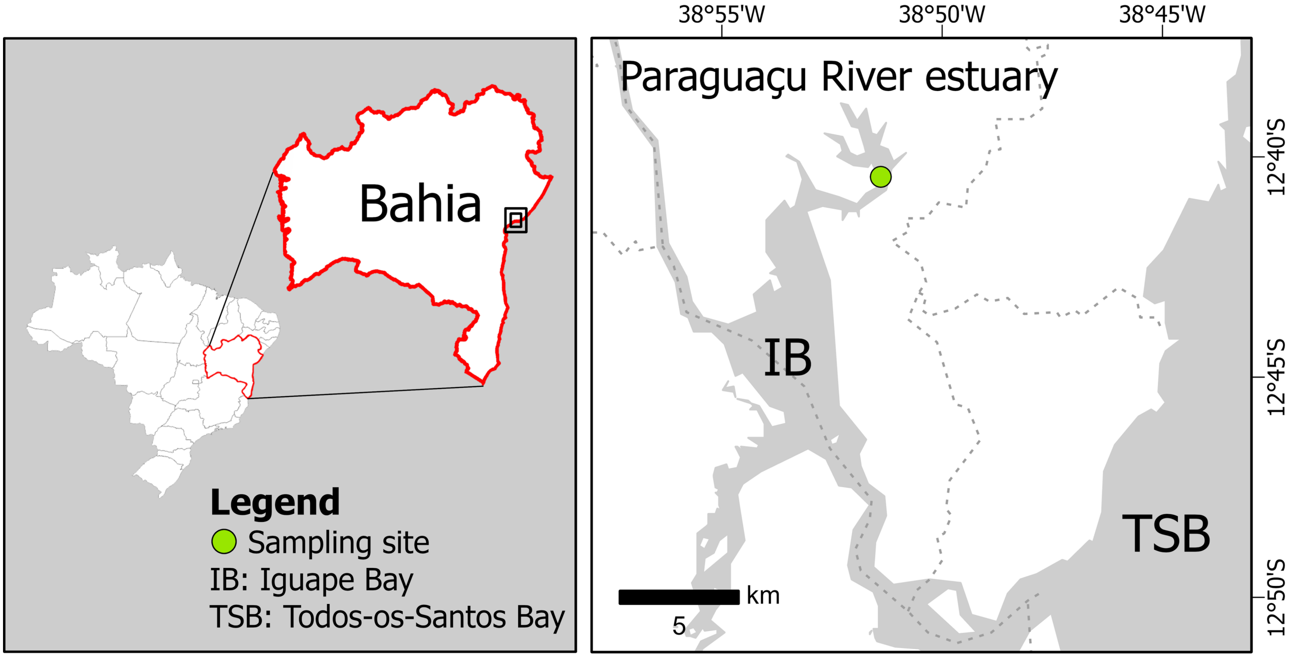

FIGURE 2. Location map showing the sampling site of the *Amorphinopsis atlantica* specimens in Iguape Bay.

C. Menegola examined type-material of other valid species of *Amorphinopsis* based on collections of the Muséum National d'Histoire Naturelle (MNHN Paris) and The Natural History Museum (NHM London, formerly BMNH), considering specimens included in our results or comments from other international museums and surveys as follow: SMF—Senckenberg Naturmuseum Frankfurt, Frankfurt, Germany; USNM – National Museum of Natural History, Smithsonian Institution, Washington DC, USA; ZMB—Museum für Naturkunde, Berlin, Germany; ZSI-M—Zoological Survey of India, Mylapore, Madras, India. These data provided further details of the external morphology and spicule measurements of other species of *Amorphinopsis*, for comparative purposes against the population of *A. atlantica* from Iguape Bay.

Systematics

Phylum Porifera

Class Demospongiae

Subclass Heteroscleromorpha

Order Suberitida Chombard & Boury-Esnault, 1999

Family Halichondriidae Gray, 1867

Genus *Amorphinopsis* Carter, 1887

***Amorphinopsis atlantica* Carvalho, Hajdu, Mothes & van Soest, 2004**
Fig. 3

Material examined. UFBAPOR 5019, Iguape Bay/Paraguaçu River estuary, Cachoeira (Bahia, Brazil), (12°40′26″ S; 38°51′24″ W); on mud, 0.0 m depth; coll. V. C. Veloso-Junior (13.XI.2019); specimen measurements: 55 mm length, 46 mm width, and 60 mm thickness. UFBAPOR 5020, Iguape Bay/Paraguaçu River estuary, Cachoeira (Bahia, Brazil) (12°40′26″ S; 38°51′24″ W); pneumatophores and rhizophores of mangrove trees, 0.0 m depth; coll.

V. C. Veloso-Junior (13.XI.2019); specimen measurements: 132 mm length, 52 mm width, and 47 mm thickness. UFBAPOR 5021, Iguape Bay/Paraguaçu River estuary, Cachoeira (Bahia, Brazil) (12°40′26″ S; 38°51′24″ W); wood fish trap, 0.0 m depth; coll. V. C. Veloso-Junior (13.XI.2019); specimen measurements: 73 mm length, 74 mm width, and 36 mm thickness.

Additional comparative material examined.

Amorphinopsis fistulosa (Vacelet, Vasseur & Lévi, 1976) as *Prostylissa fistulosa* Vacelet *et al.,* 1976, (Holotype MNHN DVVL 51, western and northern Madagascar).

Amorphinopsis kempfi Kumar, 1925, (schizotype loaned to MNHN from the holotype ZSI -MP.199/1).

Amorphinopsis maza (de Laubenfels, 1954) as *Nailondria maza* de Laubenfels, 1954, (schizotype loaned to MNHN, from the holotype USNM 23083).

*Amorphinopsis pallescen*s (Topsent, 1892) as *Hymeniacidon pallescens* Topsent,1892 (holotype MNHN-DT-2384 (spicules) & MNHN-DT-2385 (thick section), Western. Mediterranean).

Amorphinopsis papillata (Baer, 1906) as *Ciocalypta papillata* Baer, 1906, (schizotype loaned to MNHN from the type series SMF 685, 1818 and ZMB 3193).

Amorphinopsis siamensis (Topsent, 1925) as *Prostylissa siamensis* Topsent, 1925, (MNHN-DT-1882, 1885, 3453 and 2083)—Siam Gulf).

Amorphinopsis excavans Carter, 1887 (holotype BMNH 1981.10.14.3, Mergui Archipelago, Indian Ocean)

Amorphinopsis armata (Lindgren, 1897) as *Halichondria armata* Lindgren, 1897*,* (holotype BMNH 1929. XI.26.3, Malayischen Archipelago, Chinese Seas).

Description of external morphology. *Amorphinopsis atlantica* is an encrusting, massive, cushion-shaped or lobate sponge presenting a rough surface and is easily detachable. The sponge is slightly compressible. *In vivo*, it is yellow to dark greyish green in color. It is bright yellow in areas protected from direct sunlight. Specimens turn brownish after fixation (80% ethanol). The subectosomal canals are visible to the naked eye.

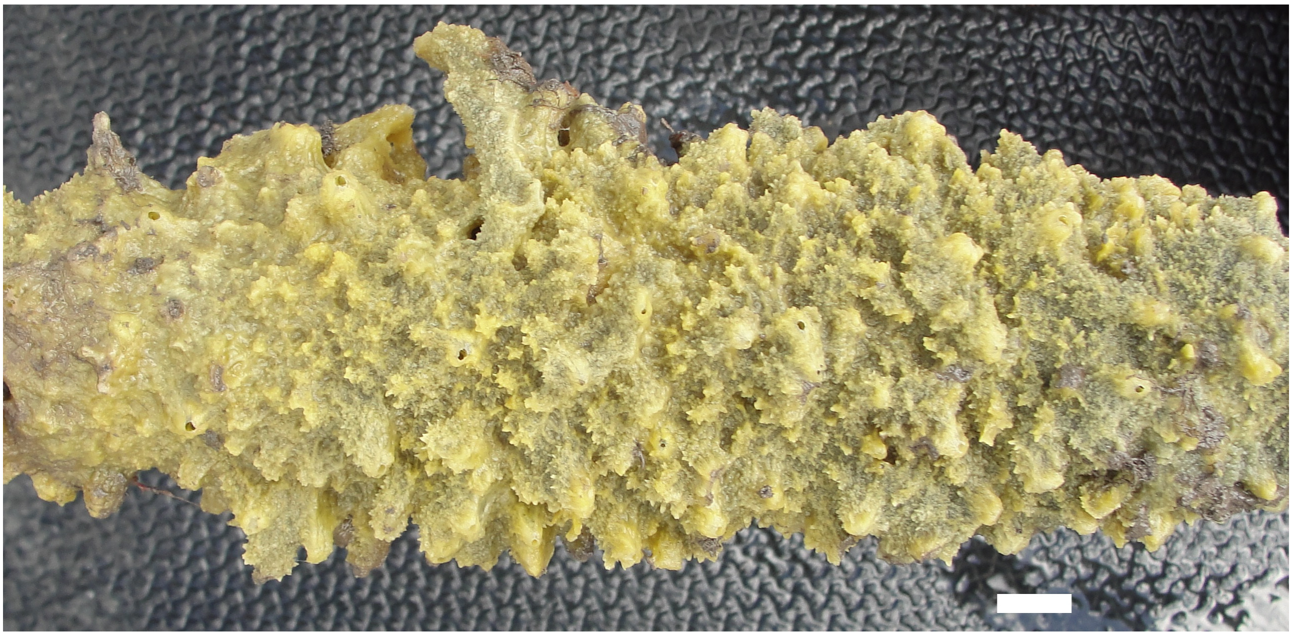

FIGURE 3. Specimen of *Amorphinopsis atlantica* from Iguape Bay. White scale bar = 5 cm.

Skeleton and spicules. The ectosomal skeleton is formed by scattered spicules in a complex arrangement. In contrast, the choanosomal skeleton is lacunar and formed by multiple spicular fibers of large oxeas (Fig. 4). There are two types of spicules: oxeas (Fig. 5A, B, and D), and styles (Fig. 5C and E). The oxeas are straight or slightly curved, with needle-shaped or blunt tips tips (Fig. 5F). The styles are straight or slightly curved, with blunt tips. The lengths and widths (minimum-median-maximum) of oxeas and styles are, respectively, 145.8-441.2-689 µm long / 3.3-11.8-19.9 µm wide, and 132.5-159.9-212 µm long / 3.3-4.8-6.6 µm wide.

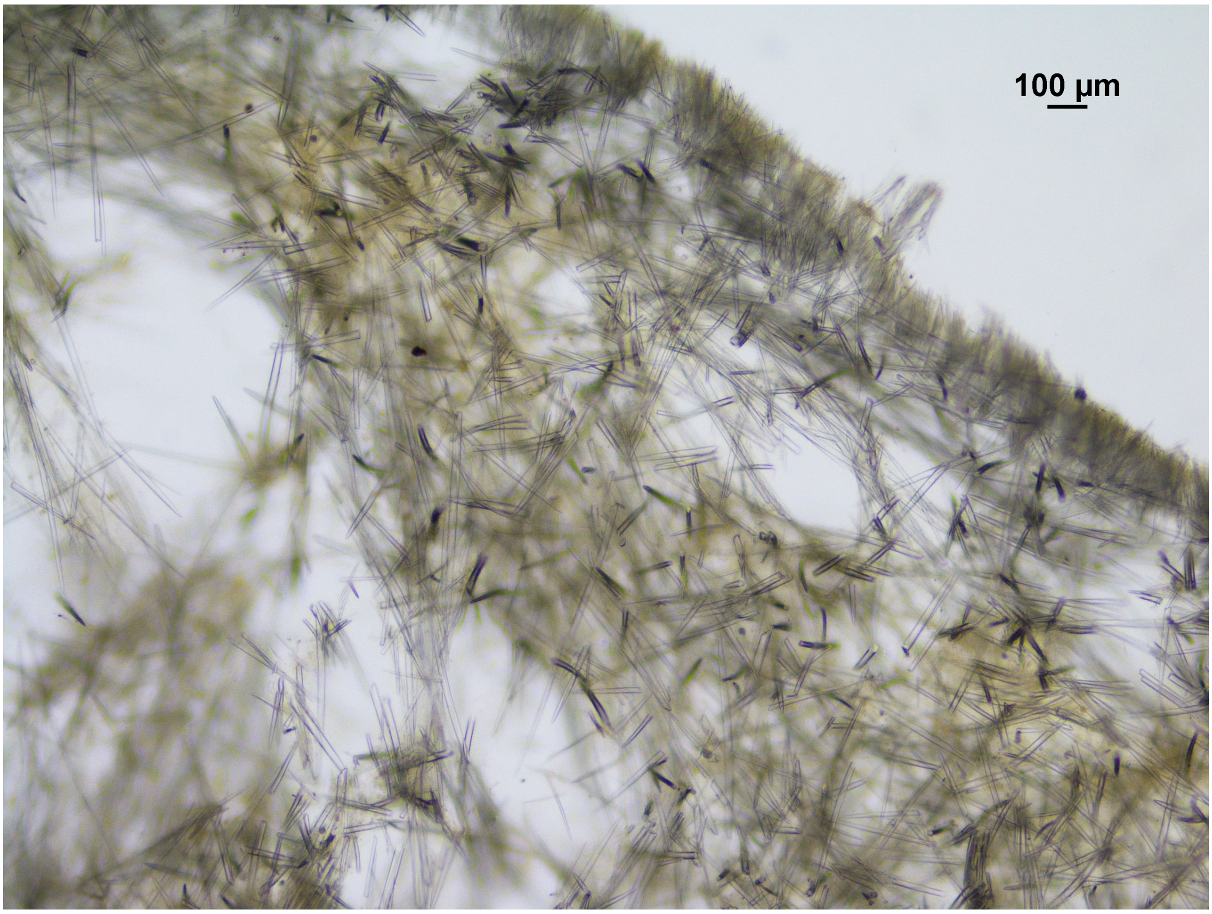

FIGURE 4. Skeleton architecture thick section of *Amorphinopsis atlantica*.

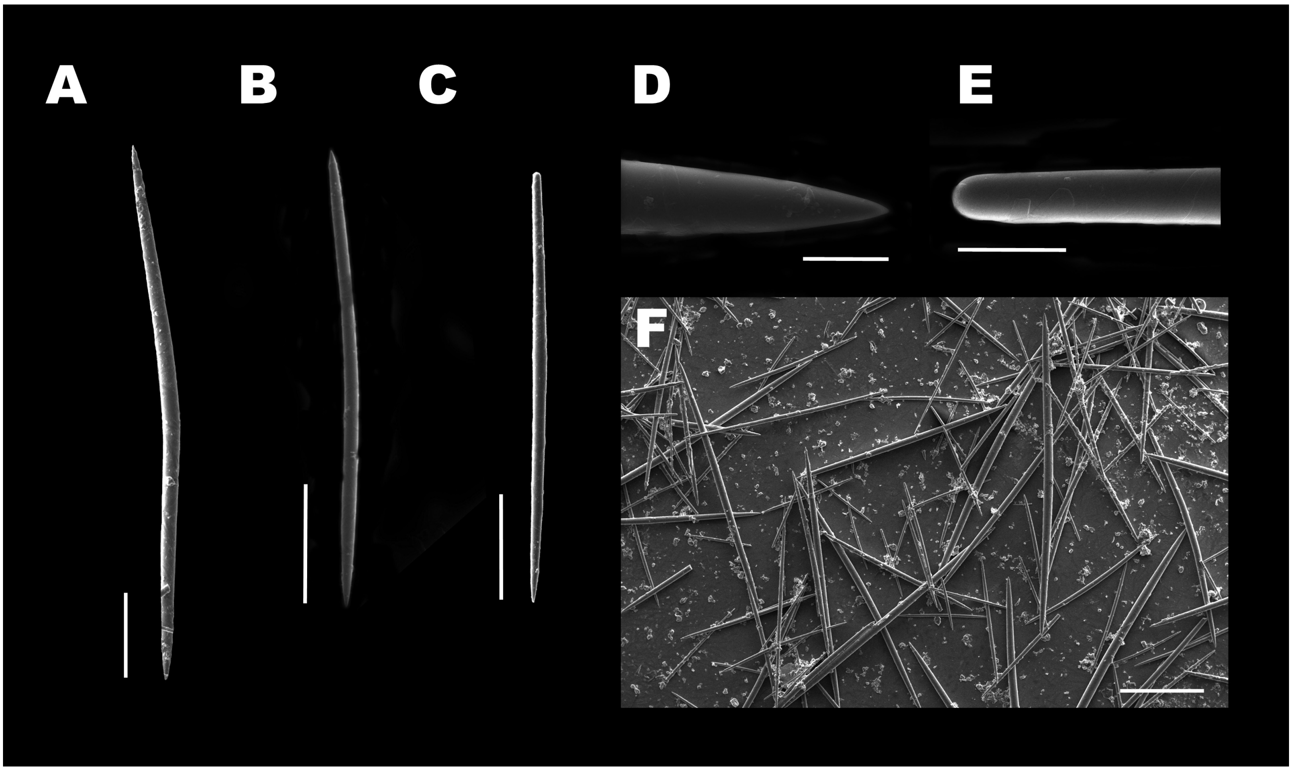

FIGURE 5. Scanning electron microscopy images of *Amorphinopsis atlantica* spicules. (A and B) Two oxeas varying in size and curvature. (C) Style. (D) Detail of the tip of the oxea. (E) Detail of the tip of the style. (F) General view of oxeas and styles. Scale bars: A, B = 250 µm; C = 50 µm; D, E = 10 µm; F = 200 µm.

Natural history. The specimens were found mainly in the rigid parts of mangrove trees, on hard substrates lying in the mud, and on fish traps made from mangrove stakes. Other specimens attached to rocks, piers, and concrete constructions were also observed in Iguape Bay. In the fish traps, the sponges were associated with oysters, barnacles, macroalgae, young crabs, and specimens of the anemone, *Diadumene lineata* (Verril, 1869), which have successfully invaded coastal waters in many regions around the world (see Fofonoff *et al*. 2018). During the low tide of spring tides, some sponges were constantly exposed to sunlight and desiccation.

Distribution. Brazil: Northeastern (Pernambuco and Paraíba States: Santos *et al.* 2018; Bahia State: present study) and southeastern (Rio de Janeiro and São Paulo States: Carvalho *et al*. 2004) regions. Mexico: Gulf of Mexico (de La Cruz *et al*. 2019). North Caribbean: Belize (Diaz & Rüetzler, 2009). South Caribbean: Colombia and Venezuela (Morrocoy National Park and La Restinga Lagoon National Park) (Guerra-Castro *et al*. 2016). The present study expands the distribution of this species within northeastern Brazil.

Discussion

In the present study, we followed the current systematic usage of the World Porifera Database (de Voogd *et al*. 2022), following other authors studying *A. atlantica.* Our results regarding the external morphology of *A. atlantica* and its spicule set (spicule categories and dimensions) are similar to those reported by other authors, such as Carvalho *et al*. (2004), Santos *et al*. (2018) and De la Cruz-Francisco *et al.* (2019) (Table 1).

TABLE 1. Comparison of spicule dimensions of *Amorphinopsis atlantica* specimens from various geographic regions at Brazil and Mexico. Values are expressed as minimum–mean–maximum length/ width (N = 30).

Specimens	Oxeas (µm)	Styles (µm)
Carvalho *et al*. (2004; holotype MNRJ 353), original description (Brazil)	155–392.3–825/8–15.5–23	143–178.6–221/5–6.6–8
Santos *et al*. (2018; UFPEPOR 1666), original description (Brazil)	180–568.8–1000/5–15.2–31.2	130–283.2–650/2.4–9.9–20
de la Cruz-Francisco *et al*. (2019; holotype FBUVP-00001), original description (Mexico)	160–511.6–755/6–9.5–18	130–146.1–180/6–6.2–8
Present study	145.8–441.2–689/3.3–11.8–19.9	132.5–159.9–212/3.3–4.8–6.6

The sites mentioned by Carvalho *et al.* (2004) for *A. atlantica*, viz. Cabo Frio, and São Sebastião Channel are not estuaries, as is Iguape Bay. Indeed, the most critical coastal feature in the Cabo Frio region is the upwelling (Calado *et al.* 2018), while in the São Sebastião Channel where coastal waters are predominant without any freshwater runoff (Oliveira & Marques 2007). The operation of a dam and a hydroelectric power plant in the tidal river of Iguape Bay region has changed the river dimensions (*sensu* Ward, 1989), and consequently the whole estuary. Genz & Lessa (2015) indicated that the lower estuarine course of the Paraguaçu River could be classified as highly impacted by the dam, as far as hypersalinization is concerned, which used to be the most extensive freshwater input to the Todos-os-Santos Bay (Wolgemuth *et al.* 1981). More recently, Mariani *et al.* (2021) confirmed that the hypersalinity events appear to have come around in the early 1990s and that the salinity throughout the bay is sensitive to the summer discharges of the Paraguaçu river. These extreme hydrological changes reduced the salinity range and sediment load and the river flow regime to a changing condition, allowing the colonization of new organisms (Reis-Filho *et al.* 2010), such as the sun-coral, *Tubastraea* spp (Miranda *et al.* 2016; Creed *et al.* 2017), the anemone, *D. lineata* (Longo, pers. comm.), the Indo-Pacific swimming crab, *Charybdis helleri* (Carqueija & Gouvea 1996), and the mud sleeper fish, *Butis koilomatodon* (Barros *et al.* 2018). Therefore, *A. atlantica* in Iguape Bay suggests an invasive behaviour, given that it is found in an estuary with continuous salinity variation. Similar to the findings reported in the literature (Carvalho *et al.* 2004; Santos *et al.* 2018; De la Cruz-Francisco *et al.* 2019), the populations *A. atlantica* in Brazil are opportunists that take advantage of any new rigid substrate to colonize, such as ports and shipyards or fishing trap poles, facilitating the spreading of the species,

Owing to its high spicular density, pointed spicules, as well as its microscopic size and wide distribution in Iguape Bay, it has been alleged by local fishers since 2006 that this sponge is causing skin dermatitis afflicting the local population. Similar afflictions have also been reported in Colombia, in the Cispatá Bay, where the sponge irritates the skin (swelling and red marks), according to Quirós-Rodriguez (pers. comm.), but these anecdotal reports need to be empirically investigated.

In Iguape Bay, the low energy environment, reduced salinity range and sediment load, and lack of competition with other species, as mangrove trees do not have a dense cover of bostrychietum , may constitute conditions likely to favour the settlement of the sponge in question.

The identification of *A. atlantica* in the Iguape Bay represents the first record of this species in Bahia, extending its distribution to tropical coastal environments (Santos *et al*. 2018). On the other hand, we would not expect to find this species in an estuarine environment, where salinity variation is conspicuous. Such a fact could be diagnosed as an "invasive" species behaviour, thus raising concerns over the possible impacts and risks of such invasion on the local benthic communities and the sustainability of traditional fisheries harvesting activities.

Monitoring and assessing the distribution and abundance of this sponge species in Iguape Bay are required to confirm its invasive impacts on the local fauna and flora, and its alleged role in causing skin dermatitis, as complained by the local fisher population, requires confirmation by empirical evidence.

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