ARTICLE

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THE EXOTIC BIVALVE *Electroma vexillum* (REEVE, 1857) (BIVALVIA: VULSELLIDAE) ON THE BRAZILIAN COAST

O bivalve exótico Electroma vexillum *(Reeve, 1857) (Bivalvia: Vulsellidae) na costa brasileira*

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ABSTRACT

The presence of the Indian Ocean and Red Sea bivalve *Electroma vexillum* (Reeve, 1857) was observed for the first time on the coasts of Ceará and Piauí. The occurrence of *Electroma vexillum* was recorded in association with solid waste deposited in the wrack zone, algae and marine angiosperm samples, on sandy beaches, sandstone reefs and sand-mud flats in estuarine areas. Local fishermen also reported the bivalve attached to nets and other fishing gear. The shell of *E. vexillum* is inequivalve, with the left valve being flattened and the right valve convex, overlapping the left. The average length of the specimens was 7.8mm, with and average length/height (L/H) ratio of 1.36mm. Further investigations are necessary to assess the ecological impact of this bivalve, which has previously caused damage to oyster farming structures in its native range. The potential consequences to native fauna, coastal ecosystems and mariculture facilities in Brazil raise concerns, emphasizing the urgency for continued monitoring and mitigation efforts. The recently described *Electroma electra* Simone, 2024 is discussed.

Keywords: Invasive species, Marine litter, Coastal ecosystems.

RESUMO

A presença do bivalve do Oceano Índico e do Mar Vermelho *Electroma vexillum* (Reeve, 1857) foi observada pela primeira vez nas costas do Ceará e Piauí. A presença de *Electroma vexillum* foi registrada em associação com resíduos sólidos depositados na zona de arribação, amostras de algas e angiospermas marinhas, em praias arenosas, recifes de arenito e bancos areno-lamosos em áreas estuarinas. Pescadores locais também relataram a presença do bivalve aderido a redes e outros equipamentos de pesca. *E. vexillum* apresenta conchas inequivalves, com a valva esquerda sendo achatada e a valva direita convexa, sobrepondo a esquerda. O comprimento médio dos espécimes foi de 7,8 mm, com uma relação média de comprimento/altura (C/A) de 1,36 mm. Investigações adicionais são necessárias para avaliar o impacto ecológico deste bivalve, que já causou danos às estruturas de cultivo de ostras em sua área nativa. As potenciais consequências para a fauna nativa, os ecossistemas costeiros e as instalações de maricultura no Brasil geram preocupações, ressaltando a urgência de um monitoramento contínuo e de esforços de mitigação. A recente descrição de *Electroma electra* Simone, 2024 é discutida.

Palavras-chave: Espécie exótica. Lixo marinho. Ecossistemas costeiros.

1 INTRODUCTION

Two of the greatest threats to marine biodiversity are habitat modification and the introduction of invasive species (Early *et al.*, 2016; Anton *et al.*, 2019). Non-native species also known as exotic species, are those introduced outside their natural distribution range, whether through human activities or not (Ojaveer *et al.*, 2014; Gracia & Rangel-Buitrago, 2020). The bioinvasion process is influenced by several factors, such as the ability to withstand the conditions and duration of the introduction process, capacity to form resting stages, life history strategies with pelagic larval dispersal or direct development, reproduction rates, ability to overcome abiotic factors and adaptation to a new trophic niche (Streftaris *et al.*, 2005).

Marine bioinvasion is a growing and concerning phenomenon, characterized by the introduction and establishment of exotic species in new marine environments, often resulting from human activities such as maritime transport, aquaculture, and tourism (de Castro *et al.*, 2017). These invasions can have significant ecological, economic, and social consequences, including competition with native species, alterations in habitats and ecosystems, and negative impacts on economic activities such as fisheries and mariculture (Kaluza *et al.*, 2010; Chandrasekar and Venkat, 2018).

Epifaunal bivalves, in particular, are frequently reported as bioinvaders due to their ability to attach to hard surfaces and their efficiency as filter feeders, enabling them to thrive in new environments. Invasive bivalve species can cause serious ecological and economic problems. They can compete with native species for space and resources, alter the composition of benthic communities, and impact human activities. A well-documented example is the golden mussel, *Limnoperna fortunei* (Dunker, 1857), which has invaded freshwater systems in South America, causing blockages in water supply systems and harming local biodiversity (De Lucia *et al.*, 2022).

In this context, the Indo-Pacific bivalve *Electroma vexillum* (Reeve, 1857) was observed for the first time along the coasts of Piauí, Ceará, and Rio Grande do Norte. These records mark the first documented occurrence of this species on the Brazilian coast, raising concerns about the potential ecological and economic impacts associated with its introduction. The arrival of *E. vexillum* is a classic example of marine bioinvasion, underscoring the need for continuous monitoring and mitigation strategies to protect coastal ecosystems and native biodiversity. The sudden appearance of large numbers of a small, byssally attached bivalve not previously recognized in the shallow waters of the

coasts of Piauí, Ceará, and Rio Grande do Norte suggested that an alien invasive event has taken place.

Species Characterization

Electroma vexillum: the shell is a small, fragile, semi-transparent, decorated with brown zigzag patterns of variable intensity. Outline obliquely wedge-shaped with a deep byssus notch in the left valve; inequivalve, with the convex right valve overlapping the left; inequilateral with the beaks toward the anterior. For comparison see Alagarswami & Chellam (1976), Asha *et al.* (2016); Borrero & Díaz (1988); Oliver *et al.* (2023), *Electroma vexillum* is rather variable in outline and colour pattern as can be seen in shells this study and from Kuwait (Figure 1).

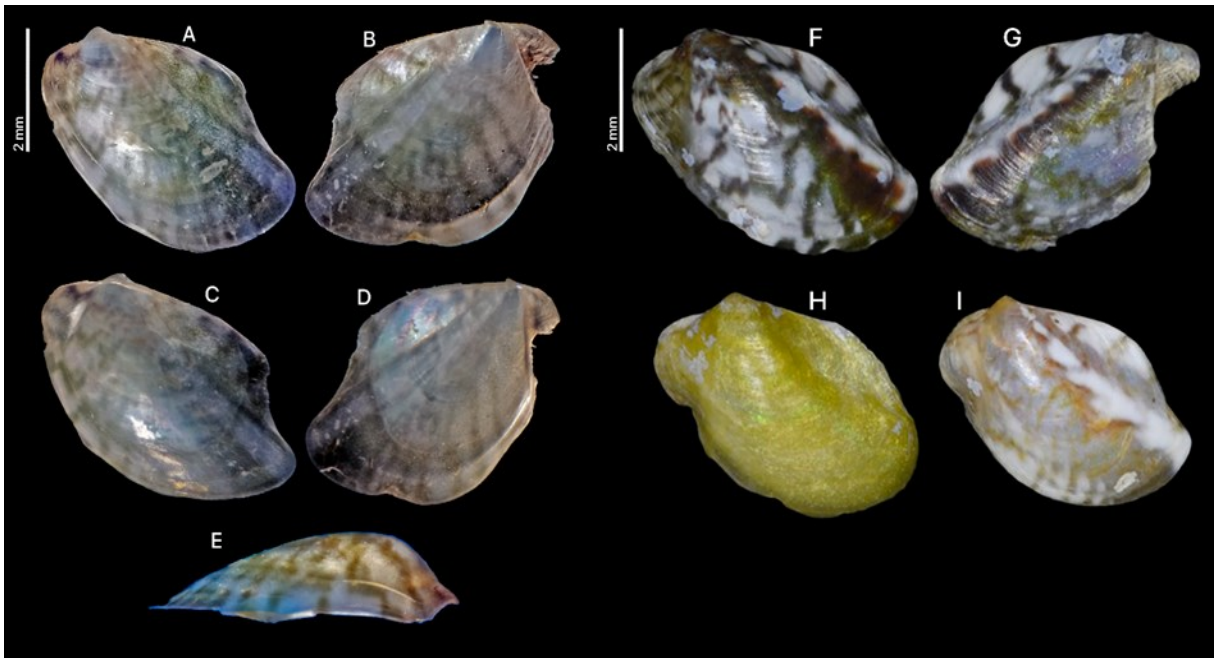

Figure 1. *Electroma vexillum* shells collected in this study (Brazil): a. external view of the left valve; b. external view of the right valve; c. internal view of the left valve; d. internal view of the right valve; e. lateral view of the valves. *Electroma vexillum* shells collected from Kuwait illustrated by Oliver *et al.* (2023): f. external view of the left valve; g. external view of the right valve; h. and i. variation in shell coloration.

Typically found attached to marine angiosperms (Figure 2), hard substrates, or hydroids, it uses byssus threads for adherence. It inhabits high-salinity environments (~38 PSU) with variable temperatures ranging from 23°C to 36°C and is commonly observed in thermal discharge channels due to the stability of these conditions (Çevik *et al.*, 2008).

The collected specimens were measured using a digital calliper with 0.01 mm precision and photographs were taken for identification. P. Graham Oliver identified the specimens at the National Museum of Cardiff, United Kingdom, and subsequently deposited in the Malacological Collection of Professor Henry Ramos Matthews (Series A) at the Universidade Federal do Ceará (CMPHRM5658A-5687A). The average length of the specimens found was 7.8 ± 0.7 mm, with an average Length/Height ratio of 1.36 ± 0.3 mm, consistent with previously reported measurements for the species (Çevik *et al.*, 2008).

Figure 2. Specimens of *Electroma vexillum* attached to the stems of the marine angiosperm *Halodule wrightii*.

Global Distribution of Electroma vexillum

Electroma vexillum is a bivalve native to the Indian Ocean and the Red Sea, with records from areas such as the Gulf of Aden, Yemen, Oman, Kuwait and Zanzibar, highlighting its broad natural distribution in tropical and subtropical waters (Çevik *et al.*, 2008). This species is a well-recognized Indo-Pacific invasive species recorded from the Mediterranean and Caribbean Seas over the last 30 years (Borrero & Díaz, 1998; Zenetos *et al.*, 2010)

The expansion of its distribution is likely attributed to various anthropogenic vectors, such as maritime transport and ballast water, allowing it to reach the Tropical Atlantic Ocean and the Eastern Mediterranean (Table 1).

Table 1. Global records of *Electroma vexillum* and its associated habitats.

Country	Location	Coordinates	Environment	Reference
Colombia	Santa Marta, Gulf of Morrosquillo and Puerto Bolívar	9°22' – 9°45' N; 75°33' – 75°55' W	Attached to hydroids (*Cnidoscyphos sp.*) and algae (*Sargassum sp.*), depths of 4 to 10 m, associated with algae	Borrero & Díaz, 1998
Venezuela	Tucacas beaches	10°47'52'' N; 68°19'03'' W	Associated with beach debris and stomach contents of catfishes (*Ariidae*)	Borrero & Díaz, 1998
Mozambique	Southern bay of Inhaca Island	26°07' N; 32°56 E	Old coral debris and rocks, with small patches of seagrass vegetation (*Halodule wrightii* and *Cymodocea serrulata*)	De Boer & Prins, 2002
Türkiye	Iskenderun	36°34'54'' N; 36°09'54'' E	Found in the discharge canals of the Iskenderun Iron and Steel Factory, where hot water is discharged into the sea	Çinar *et al.*, 2005
Türkiye	Iskenderun Bay, Hatay Province	36°11.2' N; 36°43.1' E	Found attached to cement walls of a canal and on hydroids, at a depth of 80 cm	Çevik *et al.*, 2008
Greece, Türkiye, Cyprus, Syria, Lebanon, Palestine, Egypt	Eastern Mediterranean	-	-	Zenetos *et al.*, 2010
Türkiye	Iskenderun Bay	-	-	Albayrak, 2011
India	Tuticorin Port	08°46'0'' N; 78°11'0'' E	On stems of seagrasses such as *Cymodocea serrulata*, *Halophila ovalis*, and *Syringodium isoetifolium*	Asha *et al.*, 2016
Kuwait	Ras Al-Zour (Kuwait Bay)	-	Attached among sessile epifauna or algae	Oliver *et al.*, 2023

In the Indian Ocean, *E. vexillum* has been observed in the southern bay of Inhaca Island, Mozambique, among old coral debris and seagrass vegetation such as *Halodule wrightii* and *Cymodocea serrulata* (De Boer & Prins, 2002). On the Indian coast, it was reported in Tuticorin Port, attached to the stems of seagrasses such as *Cymodocea*

serrulata, *Halophila ovalis*, and *Syringodium isoetifolium* (Asha *et al.*, 2016). In the northern Arabian Gulf, it was recently recorded from Kuwait attached to Sargassum in large numbers (Oliver *et al.* 2023).

In the Eastern Mediterranean, *E. vexillum* was identified in Iskenderun Bay, Turkey, attached to cement walls and hydroids in thermal discharge canals (Çevik *et al.*, 2008). This record was further complemented by reports from the same region, including the Turkish coast at Iskenderun (Çinar *et al.*, 2005; Albayrak, 2011) and other locations in the Eastern Mediterranean, such as Greece, Cyprus, Syria, Lebanon, Palestine and Egypt (Zenetos *et al.*, 2010).

In the Tropical Atlantic Ocean, *E. vexillum* was recorded in Colombia, in Santa Marta, the Gulf of Morrosquillo and Puerto Bolívar, attached to hydroids (*Cnidoscyphos* sp.) and algae (*Sargassum* sp.) at depths of 4 to 10m, as well as in Venezuela, on Tucacas beaches, associated with beach debris and the stomach contents of catfish (*Ariidae*) (Borrero & Díaz, 1998).

Occurrence Records in Brazil

The presence of the exotic bivalve *Electroma vexillum* was recorded at various locations along the northeastern coast of Brazil, specifically in the states of Ceará, Rio Grande do Norte, and Piauí, between 2022 and 2023 (Table 2; Figure 3). These findings represent the first reports of this species in Brazilian waters, marking its expansion into the South Atlantic and highlighting its potential to colonize a variety of coastal and marine environments. The initial records were documented in May 2022 in Fortaleza, Ceará, where specimens were found attached to plastic debris in the surf zone and on gravel substrates in the infralittoral zone (30 – 60m) at Iracema and Meireles beaches. Subsequently, in January 2023, clusters of bivalves were observed during spearfishing dives at a depth of 20 meters in Macau, Rio Grande do Norte. In Ceará, specimens of *E. vexillum* were also recorded in the Pacoti river estuary and at Batoque Beach, occupying intertidal and subtidal zones, where they were often associated with marine vegetation such as *Halodule wrightii* and macroalgae. Similarly, in Rio Grande do Norte, *E. vexillum* was observed at Baixa Grande Beach, where it was also associated with macroalgae. In Piauí, the species was found on the right bank of the Timonha River mouth, attached to seagrass vegetation associated with *Halodule wrightii* and *Halodule beaudettei*.

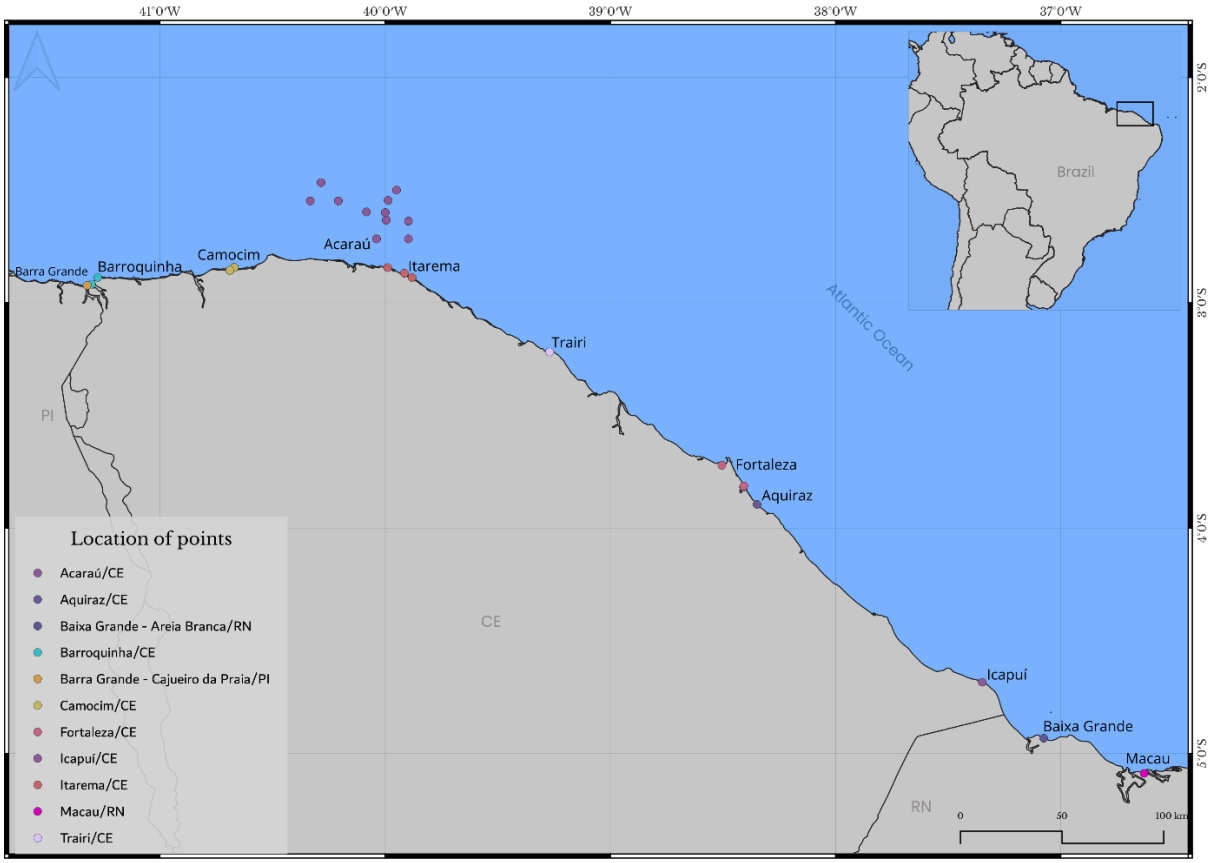

Figure 3. Map showing the known distribution of *E. vexillum* along the semi-arid Brazilian coast.

Table 2. Geographical and environmental data of *Electroma vexillum* occurrences in coastal areas of Northeastern Brazil.

Date	City	Coordinates	Locality	Depth	Attached to
15/V/2022	Fortaleza - CE	3°43'22.0"S; 38°30'10.1"W	Iracema Beach	± 2.5 m	Sand (plastic debris)
16/V/2022	Fortaleza - CE	3°43'27.12"S; 50°29'45.24"W	Meireles Beach	infralittoral (up to 20 m)	Gravel
15/VI/2022	Fortaleza - CE	3°41'56.4"S; 50°30'12.0" W	Meireles Beach	subtidal (up to 20 m)	Plastic debris
20/I/2023	Macau - RN	5°04'41.9"S 36°37'46.5"W	-	subtidal (20 m)	Gravel
02/II/2023	Itarema-CE	-	-	12 m	Collected from fishing lines
17/III/2023	Acaraú-CE	2°32'32.3"S; 40°19'58.3"W	-	subtidal (up to 20 m)	
22/III/2023	Camocim-CE	2°50'34.8"S; 40°40'01.2"W	-	intertidal	*Halodule wrightii*
23/III/2023	Barroquinha-CE	2°55'04.8"S; 41°18'14.4"W	Left bank of the Timonha River mouth	intertidal	*Halodule wrightii* and *Halodule beaudettei*
23/III/2023	Barra Grande-PI	2°55'24.7"S; 41°19'42.5"W	Right bank of the Timonha River mouth	intertidal	*Halodule wrightii* and *Halodule beaudettei*
18/IV/2023	Fortaleza-CE	3º49'04.29"S; 38º24'34.56" W	Estuary of the Pacoti River	intertidal	*Halodule wrightii*
V/2023	Camocim-CE	2°50'12.5"S; 40°37'34.3"W	Guriú	intertidal	*Halodule wrightii*
06/VII/2023	Icapuí-CE	4º41'2"S; 37º20'58"W	Cajuais Bank	intertidal	*Halodule wrightii*
7/VII/2023	Camocim-CE	2°51'21.6"S; 40°41'24.0"W	Lagoa Grande mouth	intertidal	macroalgae + *Halodule wrightii*
7/VII/2023	Camocim-CE	2°50'34.8"S; 40°40'01.2"W	Tatajuba sandstone reef	intertidal	macroalgae + *Halodule wrightii*
01/VIII/2023	Itarema-CE	2°52'08.4"S; 39°54'54.0"W	Porto dos Barcos	intertidal	*Halodule wrightii*

03/VIII/2023	Itarema-CE	2°50'38.4"S; 39°59'20.4"W	Espraiado	intertidal	*Halodule wrightii*
24/VIII/2023	Aquiraz-CE	4°00'04.0"S; 38°13'45.0"W	Batoque Beach	intertidal	Collected from fishing nets
VIII/2023	Areia Branca - RN	4°55'54.1"S; 37°04'39.1"W	Baixa Grande Beach	intertidal	Macroalgae
28/IX/2023	Trairi-CE	3°13'06.0"S; 39°16'12.2"W	Flecheiras Beach	intertidal	Macroalgae

2 DISCUSSION

The habitats occupied by *Electroma vexillum* in Brazil span a broad spectrum of environmental conditions, ranging from intertidal zones associated with marine vegetation, such as *Halodule wrightii*, to artificial substrates like plastic debris. This ecological versatility underscores the species' remarkable adaptability, evidenced by its occurrence at varying depths—from intertidal areas to subtidal zones reaching up to 20 meters. Environmental conditions, like stable salinity and temperature, as well as anthropogenic vectors such as maritime transportation and fishing activities, may have played a pivotal role in the introduction and subsequent spread of this species along the Brazilian coastline.

The register of *E. vexillum* as an invasive species in Brazil raises critical ecological concerns, particularly given its documented impacts in other regions, including the Mediterranean Sea and Turkish coastal waters. In these areas, *E. vexillum* invasions have been closely linked to phenomena such as climate change and human activities, creating conditions conducive to colonizing unoccupied ecological niches (Streftaris *et al.*, 2005; Galil & Zenetos, 2002). Previous studies have highlighted the ability of invasive bivalves to thrive in diverse habitats due to their phenotypic plasticity and effective reproductive strategies—traits that are also evident in *E. vexillum* (Çevik *et al.*, 2008).

In the context of Brazil, the occurrence of this species on plastic debris reveals a direct connection between bioinvasion dynamics and marine pollution. Plastic waste serves as an artificial substrate that facilitates attachment, transport, and establishment of the species, effectively creating microhabitats that promote its dispersion throughout coastal and marine environments. This relationship underscores the amplifying role of

human-mediated pollution in enhancing the ecological impacts of biological invasions, highlighting the urgent need for integrated marine debris management within broader bioinvasion mitigation strategies.

Furthermore, the association of *E. vexillum* with the seagrass *H. wrightii* raises concerns regarding its potential effects on benthic communities. These marine plants serve as critical habitat-structuring elements, and epibiontic colonization by *E. vexillum* may disrupt native biodiversity while altering key ecological processes, including primary productivity and nutrient cycling (Çeviker & Albayrak, 2006). Such interactions could result in cascading effects on ecosystem functionality, particularly in environments characterized by high rates of endemism or biodiversity.

Recently, Simone *et al.* (2024) described a new species, *Electroma electra* Simone, Gomes & Molozzi, based on a limited number of shells collected along the Brazilian coast (from Maranhão to Espírito Santo), near sites sampled in this study. However, the morphological comparisons made by the authors were restricted to specimens from the Mediterranean and Brazil, neglecting individuals from the Indian Ocean, the type locality of *Electroma vexillum*. Given the remarkable phenotypic and chromatic variability of *E. vexillum* shells, as demonstrated in both specimens analyzed in this work (Figure 1 A-E) and those from Kuwait (Figure 1 F-I), and considering the recent and rapid expansion of this species along the Brazilian coast, it seems unlikely that *E. electra* represents a previously overlooked endemic species. Therefore, the new description likely arose from a limited interpretation of the natural morphological range of *E. vexillum*, resulting in the unnecessary creation of a new taxon. Until more detailed investigations are conducted—especially robust molecular methods, such as DNA sequencing (DNA barcoding)—the taxonomic validity of *Electroma electra* should be treated with caution. Based on ecological evidence and characteristic patterns of biological invasions, the present study provisionally identifies the collected specimens as the invasive species *Electroma vexillum*, emphasizing the urgent need for a critical reassessment of the taxonomic identity and validity of *E. electra*.

These findings emphasize the necessity for further research to elucidate the introduction pathways, ecological impacts, and interactions of *Electroma vexillum* with local benthic communities along the Brazilian coastline. Documenting the presence and behavior of this species contributes not only to the understanding of marine invasions in

the South Atlantic but also to the global assessment of how biological invaders respond to diverse ecological and oceanographic conditions.

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