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UPDATED DISTRIBUTION OF OCTOCORAL Carijoa riisei (DUCHASSAING & MICHELOTTI, 1860) IN BRAZIL INCLUDING ITS FIRST RECORD IN THE STATE OF SERGIPE, NORTHEASTERN BRAZIL

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Abstract

This study recorded, for the first time, the presence of the azooxanthellate colonial octocoral *Carijoa riisei* (Carijoidae) in the state of Sergipe, Brazil. In September 2021, colonies of *C. riisei* were observed attached to a floating pier in the estuary of the Vaza-Barris River, in the central region of the Sergipe coastline. These colonies were photographed *in situ* and collected for confirmation of their morphological identification in the laboratory. Our results represent the first recorded occurrence of *Carijoa riisei* in the state of Sergipe and contribute to filling a gap in the species distribution along the Brazilian coast. Future studies are necessary to assess the potential impacts of *C. riisei* on local ecosystems and understand the role of artificial substrates in the dispersal of invasive species.

Keywords: Artificial substrate. Biofouling. Carijoidae. Estuary. Invasive species.

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1 Introduction

Bioinvasion can be defined as the expansion of the distribution of a particular species, by human actions, intentionally or accidentally (IUCN, 2000; Defelice; Eldredge; Carlton, 2001). Currently, the occurrence of this phenomenon has increased significantly, mainly on a global scale, especially due to tourism and the transportation of commodities (Concepción et al., 2010; Rosa, 2021). It is known that the introduction of non-native species is one of the main causes of the ecosystem's biodiversity loss, leading to environmental degradation and homogenization of the local biota (MMA, 2018; Pádua et al., 2021), in addition to economic and socio-cultural impacts (Concepción et al., 2010). The early detection of such species facilitates their containment or eradication, making it possible to control them or prevent them from establishing in new environments (Rosa, 2021), and consequently impacting them.

The azooxanthellate colonial octocoral *Carijoa riisei* (Duchassaing & Michelotti, 1860), also known as snowflake coral, branched pipe coral, and orange soft coral, belongs to the Carijoidae family, and is characterized by its soft body, coloration ranging from orange to brown, with white polyps, and dense colonies formed by stolons (Bayer, 1961; Rees, 1972; Sánchez, 1994; Kahng, 2006; Venkataraman et al., 2013), which vary from 10 to 50 cm in height (Rees, 1972; Sánchez, 1994; Venkataraman et al., 2013; Galván-Villa; Ríos-Jara, 2018), and are capable of persisting for years in the environment (Kahng, 2006).

Carijoa riisei was long considered to be native to the western Atlantic and Caribbean. However, in 2010, molecular and genetic analysis using data from various locations around the world suggested that the octocoral may be native to the Indo-Pacific region (Concepcion et al., 2010), and recently spread to other regions. The species has several characteristics that promote its dispersal and success as an invasive species. Among them are the high growth rate; rapid sexual maturation (<2 years) with massive reproduction (Kahng, 2006; Kahng et al., 2008); ability to reproduce asexually by fragmentation or stolonal growth (Kahng, 2006); being a generalist filter feeder (Kahng, 2006; Lira et al., 2009; Gomes et al., 2011; Sánchez; Ballesteros, 2014); and, although it has predators, such as the fish *Holacanthus passer* Valenciennes, 1846 and the nudibranchs *Phyllodesmium poindimiei* (Risbec, 1928) and *Tritoniopsis* sp. Eliot, 1905, none have shown efficacy as biological control of the species (Kahng, 2006; Wagner; Kahng; Toonen, 2009; Sánchez; Ballesteros, 2014). Furthermore, the species competes heavily with other soft corals, for food and space, such as the black corals of Hawaii, including outgrowing them and compromising their immune system (Kahng; Grigg, 2005; Sánchez; Ballesteros, 2014).

Additionally, competition for space with bivalves, gastropods, and barnacles are also observed, including the colonization of their shells (Kahng, 2006).

Currently, *Carijoa riisei* has a circumtropical distribution, occurring in the Indian, Pacific, and Atlantic Oceans (Galván-Villa; Ríos-Jara, 2018; Alidoost Salimi et al., 2021). In Brazil, *C. riisei* has been recorded from Pará to Santa Catarina, except for Sergipe and Piauí (Castro; Medeiros; Loiola, 2010; Gondim; Christoffersen; Pereira-Dias, 2020). This study presents the first record of the invasive species *Carijoa riisei* in the state of Sergipe, Brazil, and the updated distribution of the species along the Brazilian coast is provided.

2 Material and Methods

Study area

The Vaza-Barris River estuary, situated within the "Área de Proteção Ambiental (APA) da Foz do Rio Vaza-Barris", established on March 30, 1990, is located between the municipalities of São Cristóvão and Aracaju on its left bank, and Itaporanga d'Ajuda on the right bank (SERGIPE, 1990; Sousa, 2011). The estuary, spanning 30 km^2, resides within a region known as pioneer formations, hosting diverse ecosystems such as mangroves, dunes, restingas (coastal tropical/subtropical forests adapted to sandy substrate and salty environments), and coastal marshes occupying fluviomarine depressions (Sousa, 2011). It has a continuous opening, an average depth of 3 to 8 m, and a semi-diurnal tidal regime, with a maximum amplitude of 2.3 m (Santos; Severi, 2019). The influence of salt water occurs up to about 20 km upstream of the river (Santos; Severi, 2019). The zone that encompasses the estuary is characterized by modest urban development and lacks port facilities. However, the area is visited for recreational boating activities (Rosa, 2021).

In September 2021, during a field trip to the Vaza-Barris River estuary, colonies of *C. riisei* were observed adhered to a pier (approximately 90 m^2) located in the region known as Orla Pôr do Sol (11°06'03"S 37°09'02"W, Figure 1). These colonies were photographed *in situ* using digital camera of Samsung A30 smartphone (Figure 2). A total of three multi-aggregated colonies of *C. riisei* were collected by scraping along the pier floats. The colonies were first demarcated with a PVC circular tube (15 cm diameter and 30 cm long). The tube was wrapped in a plastic bag to prevent the escape of associated organisms and scraping from the substrate with a spatula positioned at the base of the octocoral structure. The collected material was transferred to properly labeled plastic bags and fixed with 10% formaldehyde.

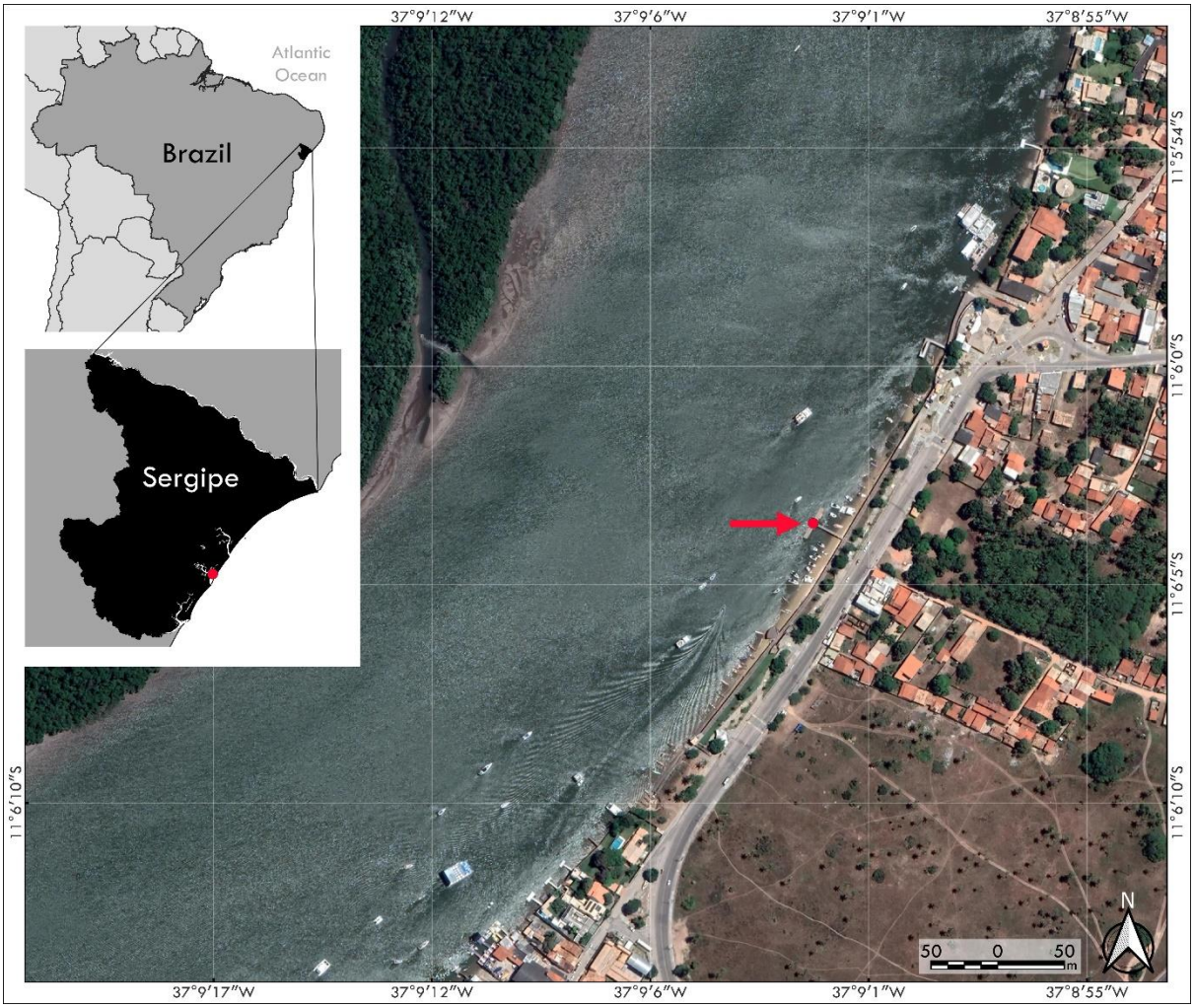

Figure 1. Map indicating the sampling site (red dot and red arrow) in the Vaza-Barris River estuary where the colonies of *Carijoa riisei* (Duchassaing & Michelotti, 1860) were collected.

Figure 2. Colonies of *Carijoa riisei* (Duchassaing & Michelotti, 1860) *in situ*, attached to the pier in the Vaza-Barris estuarine region.

The collection of organisms was authorized by the Sistema de Autorização e Informação em Biodiversidade (SISBIO Number 32380/1), Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), Ministry of Environment and Climate Change, from the Federative Republic of Brazil.

Laboratory Procedures

In the laboratory, the samples were transferred to a sieve with a mesh opening of 300 µm and washed with running water to facilitate the separation of the octocoral colonies from the rest of the associated fauna. The morphological identification of the octocorals, considering external structures, was based on the descriptions proposed by Bayer (1961), Rees (1972), Sánchez (1994), DeFelice, Eldredge, Carlton (2001), Castro; Medeiros; Loiola (2010), Venkataraman et al. (2013) and Galván-Villa and Ríos-Jara (2018). After identification, the collected material was photographed and preserved in 70% alcohol. The collected material, including the associated fauna, was deposited in the biological collection of the Benthic Ecology Laboratory (DEPAq/UFS).

3 Results and Discussion

Densely branched colonies were present throughout the whole pier substrate with > 90% coverage (visual estimate). These colonies arise from basal stolons and comprise numerous axial polyps, up to 40 cm long and 0.15 cm in diameter, reaching up to the third order (Figure 3).

Figure 3. The longest colony of *Carijoa riisei* (Duchassaing & Michelotti, 1860) collected in the Vaza-Barris estuarine region in comparison to a pen (15 cm long).

The tall axial polyps exhibit various short erect lateral polyps. The polyps are white having eight pinnate tentacles, up to 0.5 cm in length when the tentacles are retracted. These morphological characteristics of the colonies and polyps correspond to the descriptions proposed for *Carijoa riisei*.

Recently, specimens of *Carijoa* sp. were cited as basibionts of hydroids in Sergipe continental shelf (Mendonça; Guimarães; Haddad, 2022) however, the authors did not identify their specimens as *Carijoa riisei*. Thus, our results correspond the first record of the species to Sergipe, thereby filling a gap in the species distribution along the Brazilian coastline (Figure 4).

Carijoa riisei has a high degree of habitat plasticity, occurring in organic matter rich zones, attached to natural substrates such as flat sand bottoms (Sánchez, 1994), between rocks (Rees, 1972; Sánchez, 1994; DeFelice; Eldredge; Carlton, 2001), coral reefs (living or dead) and mangroves (Rees, 1972; Sánchez, 1994; Sánchez; Ballesteros, 2014), and artificial substrates such as the hulls of ships (Venkataraman et al. 2013), shipwrecks (DeFelice; Eldredge; Carlton, 2001; Sánchez, 1994; Wagner; Kahng; Toonen, 2009; Gondim; Christoffersen; Pereira-Dias, 2020), oil and gas platforms (Friedlander et al., 2014), port structures (DeFelice; Eldredge; Carlton, 2001; Kahng, 2006; Galván-Villa; Ríos-Jara, 2018), jetties, marinas, and floating docks (Venkataraman et al., 2013).

Here, the species was found attached to the floats of a pier within the estuarine region of the Vaza-Barris River. Two other biofouling invasive species, the oyster *Isognomon bicolor* (C. B. Adams, 1845) and the barnacle *Striatobalanus amaryllis* (Darwin, 1854), have also been recorded attached to piers in the same estuarine region of the Vaza-Barris River (Rosa, 2021).

Despite the absence of a port, the region has several marinas and is widely used for recreational nautical activities (Rosa, 2021). Although there is no clear evidence of movements of vessels from or to other regions, it is possible that the introduction of *C. riisei* into the Vaza-Barris River occurred by incrustation on recreational vessels, as stated in other works involving *C. riisei* (DeFelice; Eldredge; Carlton, 2001; Coles; Eldredge, 2002; Eldredge; Carlton, 2002; Kahng, 2006; Galván-Villa; Ríos-Jara, 2018) and other biofouling invasive organisms (Ulman et al., 2019; Rosa, 2021; Sempere-Valverde et al., 2023).

The secondary dispersal of *C. riisei* may have been enabled by the fixed artificial substrates in the area, such as marinas, piers and moorings, pointed out in other studies as possible stepping stones that favor the establishment of exotic species (Ordóñez et al., 2013; Coolen et al., 2018; Ulman et al., 2019; Sempere-Valverde et al., 2023), that are better competitors than the indigenous species on artificial substrates (Tyrrell; Byers, 2007, Ordóñez et al., 2013, Coolen et al., 2018), highlighting the need for characterization and monitoring of the fauna on these substrates.

However, recent studies carried out at Mexican Central Pacific showed that *C. riisei* favors the dominance of some species by increasing their abundances but reduces biological diversity of several taxa (Galván-Villa et al., 2023). These contrasting results demonstrate that the effects of *C. riisei* on adjacent community could be variable and locally-dependent.

Figure 4. Updated map of *Carijoa riisei* (Duchassaing & Michelotti, 1860) distribution along the Brazilian coast with previous species records (Castro; Medeiros; Loiola, 2010; Gondim; Christoffersen; Pereira-Dias, 2020) and highlighting the first record for Sergipe.

It is worth noting that *Carijoa riisei* acts as an ecosystem engineer serving as biogenic substrate to an variety of organisms such as algae, bryozoans, decapods, flatworms, hydroids, ophiuroids, peracarids, polychaetes, sponges, tunicates among others (Kahng, 2006; Galván-Villa; Ríos-Jara, 2018; Pádua et al., 2021; Galván-Villa, 2023). Indeed, some of the sampled colonies in this study were partly covered by tunicates, sponges, among others (Figure 5). Despite the obvious negative effects associated with invasive species, the role of *C. riisei* as biogenic substrate has increased both richness and abundance of adjacent communities as observed by Pádua et al. (2021) in artificial Brazilian shipwrecks.

Therefore, future studies to better understand the association of *C. riisei* with other taxa and its impact on the biodiversity of ecosystems is needed. Additionally, research is required to explore its interactions with invasive species, particularly regarding the facilitation of their establishment. These approaches can contribute to the knowledge of the role played by *C. riisei* in ecosystems and assist in the development of effective conservation and management strategies for these ecosystems.

Figure 5. Photographs of some colonies of Carijoa riisei (Duchassaing & Michelotti, 1860) covered by tunicates and sponges collected in the Vaza-Barris estuarine region. Scale in centimeters.

4 Conclusions

In this study, we described the occurrence of *Carijoa riisei* for the first time on the coast of Sergipe. This record fills a gap in the species distribution along the Brazilian coast. This study emphasizes the need for further research characterizing the fauna of the Vaza-Barris River estuary, the role of artificial substrates in the dispersion of invasive species, and the impacts of *C. riisei* on the ecosystem's ecology.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

All the authors contributed with the conceptualization, study design, species identification and manuscript writing.

DECLARATION OF INTEREST

The authors disclose that they have no known competing financial interests or personal relationships that could have appeared to influence the study reported in this manuscript.

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