ZOOLOGIA 42: e24071
ISSN 1984-4689 (online)

scielo.br/zool

ZOOLOGIA An International Journal for Zoology

SHORT COMMUNICATION

Spread of the invasive sun coral *Tubastraea* (Scleractinia: Dendrophylliidae) to Guanabara Bay, Brazil

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https://zoobank.org/3DBEF199-D6E2-487B-B8EB-AA12D7D6CC63

ABSTRACT. Invasive sun corals (*Tubastraea* spp.) are spreading along the Brazilian coast, competing for space with native species and altering community structure and function. This study presents the first record of *Tubastraea* sp. in Guanabara Bay, a site subject to multiple environmental stressors, including domestic sewage, industrial effluents from a densely populated area, and intense port activity. To compare morphological characteristics, we analyzed six additional samples from three locations along the coast of Rio de Janeiro, focusing on septal and columella features, calicular and colony measurements, and coenosarc coloration. The colony from Praia Vermelha exhibited a close resemblance to Morphotype I, especially the sample collected in the Cagarras Islands. In contrast, colonies from Arraial do Cabo and Ilha Grande exhibited greater variability in septal structure. The similarities between our record in Praia Vermelha and Morphotype I from the Cagarras Archipelago suggest that the proximity between these sites, along with the influence of local currents and potential transport via vessel traffic, may have facilitated the dispersion and establishment of similar morphotypes in both areas. The invasive potential of *Tubastraea* spp. remains a significant concern, and its spread may be further facilitated by frequent vessel traffic in Guanabara Bay. Although no new occurrences of *Tubastraea* spp. have been recorded at the site since May 2023, ongoing monitoring remains crucial for detecting potential future introductions and mitigating the risk of its establishment in new areas.

KEYWORDS. Biological invasion, new record, *Tubastraea*.

Biological invasion is one of the major global threats to biodiversity (Molnar et al. 2008, Bellard et al. 2016). Invasive alien species have contributed to 25% of plant extinctions and 33% of animal extinctions (Blackburn et al. 2019). Once established, these species can significantly alter local communities (Vitousek et al. 1997), disrupting ecological dynamics. They are a major driver of marine biodiversity loss (Katsanevakis et al. 2014), native ecosystem degradation, habitat destruction, and even damage to human infrastructure (Henry et al. 2023).

A notable example is the sun coral (*Tubastraea* spp.), first described by Lesson (1830) based on specimens collected in Bora Bora, French Polynesia— *Tubastraea coccinea* Lesson, 1830. *Tubastraea* includes at least 12 accepted species, most native to the Indo-Pacific region, with natural records in areas such as the Red Sea, Madagascar, and the Galápagos Islands—where *Tubastraea tagusensis* Wells, 1982 was first described and is considered native (Wells 1982, Cairns 2000, Creed et al. 2017). The genus itself was originally described based on T. *coccinea* from Bora Bora (Lesson 1830), a species with a wide Indo-Pacific distribution. Some records from the Western Pacific and Eastern Atlantic are considered cryptogenic. Since the mid-20th century, *T. coccinea* has become established in the Caribbean, Gulf of Mexico, and

Southwestern Atlantic (Fenner and Banks 2004, de Paula and Creed 2004). Additionally, species from this genus have also expanded beyond their native ranges, becoming invasive in several parts of the world.

In Brazil, *T. tagusensis* and *T. coccinea* are the two predominant sun coral species along the coastline (de Paula and Creed 2004, Soares et al. 2016, Creed et al. 2017). The sun coral has been found in Brazilian coastal municipalities, mobile artificial structures, and shipwrecks (Savio et al. 2021). Colonies of *Tubastraea* were first reported in Brazil in the mid-1980s, along the coast of Rio de Janeiro, on an oil platform in the Campos Basin (Castro and Pires 2001). Since then, sun coral has spread along the Brazilian coast, occurring mainly in the Southeast, on the coast of Rio de Janeiro (Ferreira 2003, de Paula and Creed 2004, Mantelatto 2012, Batista et al. 2013, Silva et al. 2022), São Paulo (Costa et al. 2014, Creed et al. 2017), Espírito Santo (Costa et al 2014). Furthermore, there are records in the Northeast region in Bahia, Ceará and Rio Grande do Norte (Costa et al. 2014, Creed et al. 2017), and in the South of the country, in the state of Santa Catarina. The current northern limit of *Tubastraea* occurrence in Brazil is the shipwreck Eugene Thayer (Ceará State, Northern Brazil; Soares et al. 2016), while the southern limit is in the Arvoredo Marine Biological Reserve (Santa Catarina State, Southern Brazil; Crivellaro et al. 2021).

In the state of Rio de Janeiro, the sun coral has been recorded in Angra dos Reis, Ilha Grande (de Paula and Creed 2004), Paraty (Gomes 2020), Arraial do Cabo, Búzios, and Cabo Frio (Castro and Pires 2001, Ferreira 2003, Mantelatto 2012), Macaé (Wanless et al. 2010), Cagarras Archipelago (Batista et al. 2013), and Tijucas Islands (Silva et al. 2022).

Guanabara Bay, located in Rio de Janeiro, is an eutrophicated environment primarily polluted by sewage and port operation activities (Senez-Mello et al. 2024). The bay also serves as a key anchorage for oil platforms and Floating Production Systems (FPSOs). *S*everal invasive species have been documented in the region, including the exotic mollusks *Perna perna* (Linnaeus, 1758) and *Perna viridis* (Linnaeus, 1758), as well as the Gulf toadfish *Opsanus beta* (Goode & Bean, 1880) (see de Oliveira et al. 2017, de Messano et al. 2019, Cordeiro et al. 2020), highlighting the need for a local biosecurity response and management program.

Recently, the presence of *P. viridis* has been recorded in 17 locations within Guanabara Bay, where it coexists with native species (de Messano et al. 2024). As part of that study, a benthic fauna survey conducted across 19 sites identified 83 taxa, including 11 belonging to the phylum Cnidaria, with no records of *Tubastraea*. Despite the bay's proximity to the Cagarras Archipelago and Tijucas Islands—areas where sun corals (*Tubastraea* spp.) are well established—these species had not been previously documented in Guanabara Bay. Here, we report the first record of the invasive sun coral, *Tubastraea* in this environment.

Scuba divers first observed the sun coral (*Tubastraea* sp.) colony in May 2023 at Praia Vermelha beach (Fig. 1), at the entrance of Guanabara Bay, Rio de Janeiro. The specimen was collected with the permission of the Biodiversity Authorization and Information System (SISBIO, license number 86039-5) and was deposited in the Cnidaria collection of the Museu Nacional, Rio de Janeiro, Brazil (catalog number: MNRJcnid 9466). The colony was photo-documented and removed using a hammer and chisel. It was then stored in a labeled bag and kept submerged in a bucket of seawater until it reached the laboratory.

The recorded coral specimen (Fig. 2) was sampled at Praia Vermelha (-22.957073, -43.161118) on August 4, 2023, at a depth of 7 m, located on the negative-angle side of a rocky wall, suggesting protection from direct sunlight. Located approximately 300 m from the shoreline on the right-hand side of the bay (facing the sea), the colony displayed a vibrant yellow coloration. Additionally, three isolated polyps on the same stone were removed using a chisel to prevent potential larval dispersal. After the removal, divers conducted a search, extending 50 m beyond the sampling point, covering the right side of the beach. The team has since revisited the site to inspect the area and maintain communication with divers who are regularly present in the region and dive along both rocky shores of the beach. Until recently, no new occurrences of *Tubastraea* colonies had been reported. However, in May 2025, partner local divers visually identified a few small colonies in the same area. These recent observations, while unconfirmed and based solely on visual inspection, suggest a possible reappearance that warrants further investigation.

The Appendix 1 presents a morphological description of the colony recorded at Praia Vermelha and other specimens previously collected from different sites in Rio de Janeiro state.

Three distinct morphotypes of *Tubastraea* have been documented along the southeastern coast of Brazil (Bastos et al. 2022). Two of these, characterized by placoid corallite development, are considered variations of *T. coccinea*, while the third, exhibiting phaceloid development with spaced and elongated corallites, has been identified as *T. tagusensis* based on descriptions by de Paula and Creed (2004). However, morphological and genetic analyses suggest that this third morphotype is distinct from both *T. coccinea* and *T. tagusensis*,

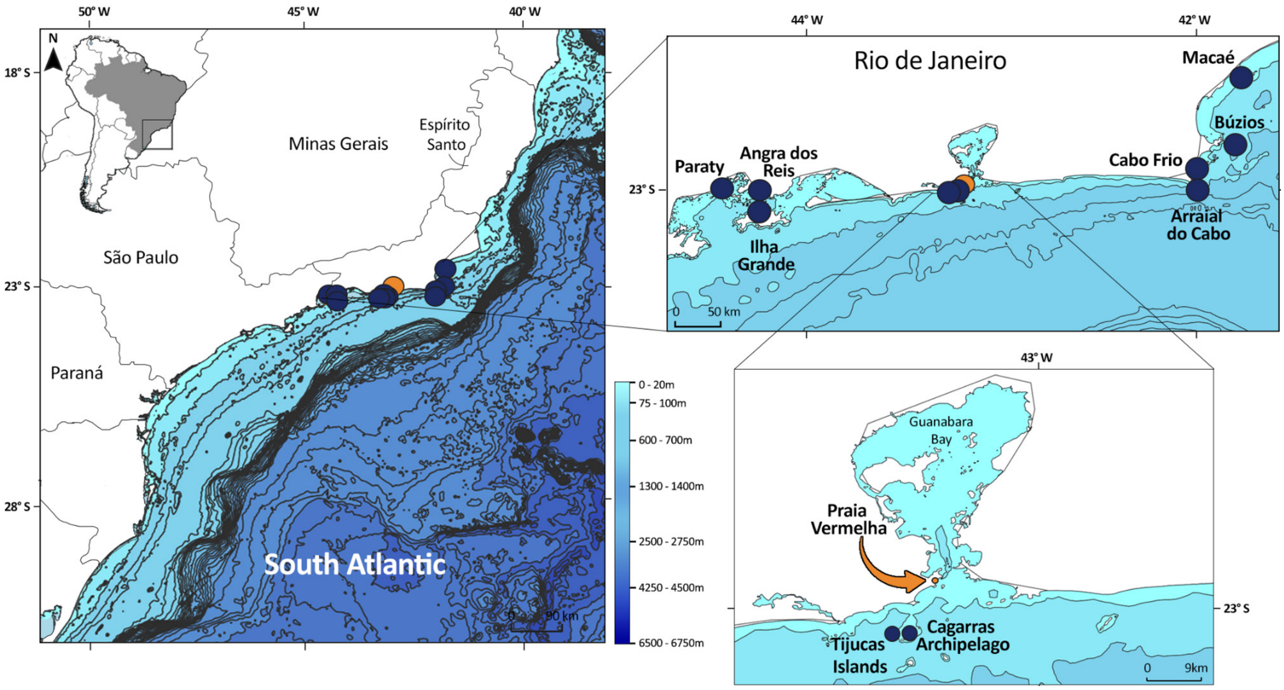

Figure 1. Map of Brazil showing the occurrence of *Tubastraea* spp. in Rio de Janeiro. Blue circles represent previously documented locations known to be infested by *Tubastraea* spp., and the orange circle indicates the new record. Previous records are based on de Paula and Creed (2004; Angra dos Reis, Ilha Grande); Gomes (2020; Paraty); Castro and Pires (2001), Mantelatto (2012), Ferreira (2003; Arraial do Cabo, Búzios, Cabo Frio); Wanless et al. (2010; Macaé); Batista et al. (2013; Cagarras Archipelago); and Silva et al. (2022; Tijucas Islands).

Figure 2. Image of the invasive *Tubastraea* sp. in Praia Vermelha, Guanabara Bay, Rio de Janeiro, Brazil.

raising questions about the correct species assignment of *Tubastraea* species in Brazil (Bastos et al. 2022). This taxonomic uncertainty poses challenges for species delimitation and consistent nomenclature within the genus.

Recently, Serra et al. (2024) described four new species of *Tubastraea* sp. from the Brazilian coast (*T. ramosa*, *T. columnata*, *T. grandidentata*, and *T. megalostoma*), based on morphology, further complicating the taxonomy of the genus in the region. This growing recognition of cryptic diversity highlights the need for a reassessment of *Tubastraea* populations in Brazil, particularly through integrative approaches that combine morphological and molecular analyses. Given that the taxonomy of species recorded in Brazil remains contentious (Bastos et al. 2022, Capel et al. 2019), we adopt a morphotype-based approach in this study, designating Morphotype I and Morphotype II, without directly assigning them to specific species.

The specimen collected at Praia Vermelha was analyzed based on descriptions from taxonomic revisions, including Cairns (1991) and de Paula and Creed (2004), and a comprehensive morphological comparison was conducted on specimens from different morphotypes. The colonies were examined based on several characters, including septal number, septal fusion, calicular diameter, corallite projection, coenosteum spacing, columella diameter, fossa depth, and coenosarc coloration.

The specimen from Praia Vermelha has a diameter ranging from 64.3 to 71.7 mm, with 48 septa arranged in the pattern S1–S2 > S3 > S4 ≤ S5. The septa are predominantly independent, although occasional fusion between S4 and S5 may occur. Axially, S1 and S2 extend to the columella, while S3 is larger than both S4 and S5 (Appendix 1 and Fig. 3A).

When comparing our record with morphotype I from Ilhas Cagarras (Fig. 3B), we observed that this specimen has a smaller diameter, possibly related to its lifespan, while maintaining a similar septal pattern. In contrast, morphotype II from Ilhas Cagarras (Fig. 3C) shows a variable number of septa, with some corallites lacking S4 septa compared to those from Praia Vermelha. Morphotype I from Ilhas Cagarras (Fig. 3B) and our record (Fig. 3A) share significant similarities.

The morphotype II samples from Ilha Grande (Fig. 3E), however, show a broader colony size range (45.9–76.4 mm) and distinct morphological features compared to the Praia Vermelha sample. Similarly, the morphotype I colony (Fig. 3D) from Ilha Grande shows a smaller diameter compared to those from Praia Vermelha.

Lastly, the colony from Praia Vermelha and Morphotype I from Arraial do Cabo (Fig. 3F) share the same maximum number of septa (48), but with different arrangements. Septa fusion occurs only in Praia Vermelha, and while both colonies have S1–S2 reaching the columella, S3–S4 do not reach it in Arraial do Cabo. The ranges for calicular diameter and corallite projection overlap, but the Arraial do Cabo specimens show greater variation. Both colonies have a moderately deep fossa and yellow coenosteum. However, the Praia Vermelha specimen presents a slender trabecular columella, whereas Arraial do Cabo's columella is irregular. Additionally, the morphotype II colony from Arraial do Cabo (Fig. 3G) exhibits greater variability in septal formation, with S4 septa being rarely present.

Regardless of species identification, our study aimed to report the new occurrence of *Tubastraea* in Guanabara Bay, emphasizing the need for further investigation to clarify the species' identity. The similarities between the Praia Vermelha specimen (Fig. 3A) and Morphotype I from the Cagarras Archipelago (Fig. 3B) may suggest a common lineage due to the proximity of the two locations, while key differences in septal fusion and colony size distinguish it from other morphotypes recorded in Ilha Grande and Arraial do Cabo.

The detection of *Tubastraea* in Guanabara Bay raises questions about its introduction pathways and potential for further spread. The genus exhibits reproductive strategies that enhance its invasive success, including sexual and asexual reproduction (Capel et al. 2017, de Paula et al. 2014), high regenerative capacity through mechanisms such as polyp bail-out under extreme conditions (Luz et al. 2018), and aggressive interactions with native species via allelopathy against competitors (Lages et al. 2012) and predators (Lages et al. 2010), as well as direct aggression (Mizrahi et al. 2017, dos Santos et al. 2013). However, their invasion success varies across environments. Previous studies indicate that factors such as water movement, substrate availability, and competition with native species can modulate the invasion dynamics of *Tubastraea* spp. (Tanasovici et al. 2022).

Although *Tubastraea* colonies were observed and sampled on the PXIII oil platform in the Campos Basin (Rio de Janeiro) in 2001, before it later docked in Guanabara Bay (de Paula and Creed 2004), no records of the species were found in subsequent surveys of the bay, as also verified by de Messano et al. (2024). This suggests that the species was either introduced recently or remained undetected in previous surveys.

The introduction and spread of *Tubastraea* spp. in Guanabara Bay also align with broader patterns of marine biological invasions, where propagule pressure plays a critical role (Couto et al. 2021). The high vessel traffic and the presence of artificial structures create multiple opportunities

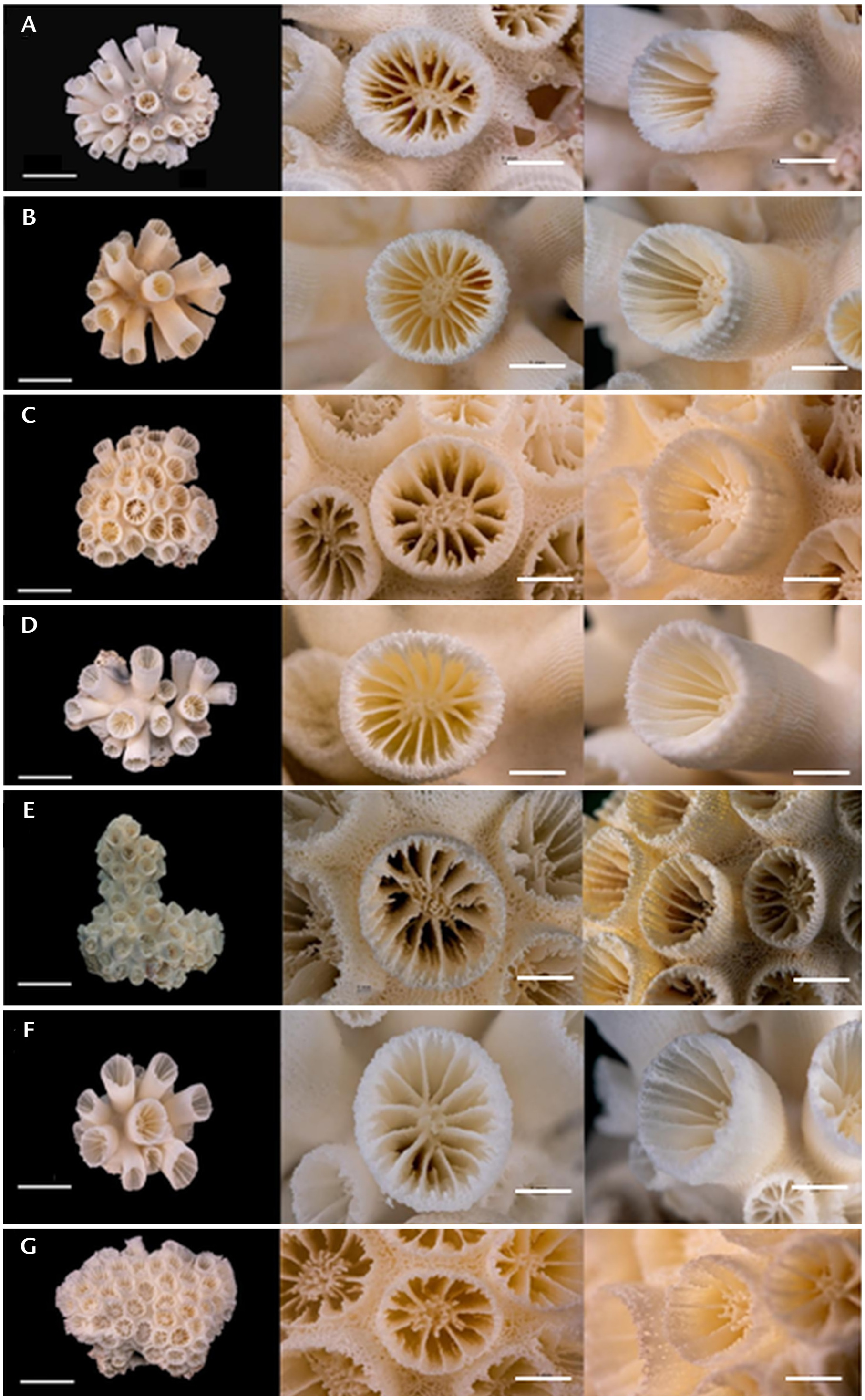

Figure 3. Morphology of *Tubastraea* spp. morphotypes. (A) *Tubastraea* sp. from Praia Vermelha; (B) Morphotype I from Ilhas Cagarras; (C) *Tubastraea* sp. Morphotype II from Cagarras Archipelago; (D) *Tubastraea* sp. Morphotype I from Ilha Grande; (E) *Tubastraea* sp. Morphotype II from Ilha Grande; (F) *Tubastraea* sp. Morphotype I from Arraial do Cabo; (G) *Tubastraea* sp. Morphotype II from Arraial do Cabo. Scale bar: left column = 1 cm; middle and right column = 1 mm.

for larval introduction and settlement. Studies assessing invasion risk (e.g., Couto et al. 2021), highlight key factors influencing the establishment of *Tubastraea* spp., including environmental similarity, substrate availability, and proximity to invaded areas.

Given the bay's proximity to already infested regions, such as the Cagarras Archipelago, and its function as a major anchorage for oil platforms and ships, the potential for secondary introductions and range expansion warrants continued monitoring and mitigation efforts. Also, due to the proximity of Praia Vermelha to the Cagarras Islands (9 km), larval transport from already established populations cannot be ruled out as a potential introduction route.

The invasive potential of *Tubastraea* is a major concern, as its continuous reproduction (Bastos et al. 2024) and regular vessel traffic in Guanabara Bay facilitate its spread (Frey et al. 2014). Early detection and monitoring are crucial for mitigating its establishment and further dispersal. A proactive approach enables rapid containment measures, reducing the ecological and economic impacts of *Tubastraea* invasions.

ACKNOWLEDGEMENTS

We are especially grateful to Thainá Cortez for her support in figure editing. We also want to thank the scuba divers Andrew Macau, Caique Ferreira, Ricardo Macieira, and Rodrigo Fedozzi for their assistance during diving operations.

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Submitted: November 11, 2024
Accepted: June 11, 2025
Editorial responsibility: Rosana M. da Rocha

Authors' Contributions

KVM: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review and editing. JAA: Conceptualization, Funding acquisition, Resources, Supervision, Validation, Writing – review and editing. MFR: Conceptualization, Funding acquisition, Supervision, Validation, Writing – review and editing. AFP: Formal analysis, Methodology, Writing – original draft, Writing – review and editing. YRC: Formal analysis, Methodology. NJ: Formal analysis, Validation. DLASA: Supervision, Validation, Writing – original draft, Writing – review and editing. FFC: Methodology, Writing – review and editing. CAMR: Supervision, Validation, Writing – review and editing.

Conflict of interest

The authors declare that no competing interests exist.

Data availability

All data generated and/or analyzed are included in this article.

Funding

This work was financed by Repsol Sinopec through the Agência Nacional de Petróleo, Gás Natural e Biocombustíveis (ANP) Research and Development Program (Grant 23251-2). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

How to cite this article

Macieira KV, Portella AF, Jankovic N, Cunha YR, Amaral DLAS, Campos FF, Russo CAM, Americo JA, Rebelo MF (2025) Spread of the invasive sun coral *Tubastraea* (Scleractinia: Dendrophylliidae) to Guanabara Bay, Brazil. Zoologia 42: e24071. https://doi.org/10.1590/S1984-4689.v42.e24071

Published by

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Appendix 1. Morphological description of the *Tubastraea* sp. from the Praia Vermelha, Cagarras Islands, Arraial do Cabo, and Angra dos Reis, Rio de Janeiro, Brazil. Each colony has a unique deposit number, indicated in the respective column.

	Tubastraea sp. (Praia Vermelha)	Morph. I (Cagarras Archipelago)	Morph. II. (Cagarras Archipelago)	Morph I. (Ilha Grande)	Morph. II (Ilha Grande)	Morph. I (Arraial do Cabo)	Morph. II (Arraial do Cabo)
Code	MNRJcnid 9466	MNRJcni 9536	MNRJcni 9533	MNRJcni 9538	MNRJcni 9535	MNRJcni 9537	MNRJcni 9534
Corallum diameter (mm)	64.3–71.7	41.2–54.1	44.6–56.6	37.7–60.3	45.9–76.4	30.1–44.7	49–73.4
Maximum number of septa and septal arrangement	48	48	48	48	48	48	48
	S1–S2 > S3 > S4 ≤ S5	S1 ≥ S2 > S3 > S4	S1 ≥ S2 > S3 > S4	S1 > S2 > S3	S1 ≥ S2 > S3 > S4	S1 > S2 > S3 > S4	S1≥ S2 > S3 > S4
		S5 sometimes presents and > S4	S4 absent in some corallites	S4 frequently present		S4 sometimes present	S4 is not always present
Septa fusion	S4 and S5 are occasionally fused	Absent	S3 and S4 are occasionally fused	Absent	Absent	Absent	Absent
Axial limit of the septa	S1–S2 reaching the columella; S3 is rudimentary and also reaches it; S4–S5 not reaching the columella	S1–S2 reaching the columella; S3–S4 are rudimentary and do not reach the columella; S5, when present, is rudimentary	S1–S2, reaching the columella; S3–S4 not reaching the columella, S4 rudimentary	S1–S2 reaching the columella, S3 not reaching the columella, S4 rudimentary	S1–S2 reaching the columella; S3–S4 not reaching the columella	S1–S2, reaching the columella; S3–S4 not reaching the columella; S4 rudimentary	S1–S2, reaching the columella. S3 and S4 do not reach the columella. S4 rare and rudimentary
Calicular diameter (mm)	6.8–10.3	5–13.3	5.8–14.3	4.5–10.8	5.2–11.3	3.8–12.4	6.9–13.8
Projection of the corallites (mm)	6.6–17	4.5–22.5	3.1–14.4	2.5–19	3–12.9	3.2–17.3	2.4–5.0
Columella diameter (mm)	1–3	0–5	1–8	0.5–3	1–6	1–5	1–9
Fossa	Moderately deep	Moderately deep	Shallow	Moderately deep	Shallow	Moderately deep	Shallow
Coenosteum color	Yellow	Yellow	Orange	Yellow	Orange	Yellow	Orange
Columella type	Trabecular and slender	Trabecular and slender	Trabecular, irregular pattern, slender in larger corallites	Trabecular, irregular pattern, slender	Trabecular, irregular pattern, mostly round, some slender	Trabecular, irregular pattern, slender	Trabecular, round, shallow