Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Floristic surveys of the rocky intertidal zones of the Santana Archipelago, Macaé (RJ, Brazil)

Bruna de Souza Vitti
Federal University of Rio de Janeiro: Universidade Federal do Rio de Janeiro
Renan Monte de Oliveira
Federal University of Rio de Janeiro: Universidade Federal do Rio de Janeiro
Gabriela de Oliveira Almeida
Federal University of Rio de Janeiro: Universidade Federal do Rio de Janeiro
Alohany Lorena dos Santos
Federal University of Rio de Janeiro: Universidade Federal do Rio de Janeiro
Lisia Monica de Souza Gestinari
lisiagestinari@gmail.com

Universidade Federal do Rio de Janeiro https://orcid.org/0000-0002-0820-8784

Research Article

Keywords: Biodiversity, Conservation, Chlorophyta, Heterokontophyta, Rhodophyta, Taxonomy

Posted Date: October 22nd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11224011/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Floristic surveys of the rocky intertidal zones of the Santana Archipelago, Macaé (RJ, Brazil)

Bruna de Souza Vitti, Renan Monte de Oliveira, Gabriela de Oliveira Almeida, Alohany Lorena dos Santos, Lísia Mônica de Souza Gestinari
Instituto de Biodiversidade e Sustentabilidade, Universidade Federal do Rio de Janeiro, Avenida Amaro Reinaldo dos Santos Silva, 764, Macaé, RJ 27965-045, Brasil.

Bruna de Souza Vitti: ORCID https://orcid.org/0009-0005-2904-188X
Renan Monte de Oliveira: ORCID https://orcid.org/0009-0009-6928-077X
Gabriela Oliveira de Almeida: ORCID https://orcid.org/0009-0002-9862-0808
Alohany Lorena dos Santos: ORCID https://orcid.org/0009-0006-1545-8171
Lísia Mônica de Souza Gestinari: ORCID https://orcid.org/0000-0002-0820-8784
Corresponding Author: lisiagestinari@gmail.com

Abstract

Marine macroalgae play a fundamental role in maintaining the ecological balance of coastal rocky ecosystems. Limited knowledge regarding their diversity hinders the development of conservation strategies, especially in archipelago areas. The Environmental Protection Area of the Santana Archipelago suffers impacts from oil industry activities in the Campos Basin and unregulated tourism. Although several studies have been conducted in the region, its macroalgal biodiversity remains insufficiently documented. This study conducted a taxonomic survey of seaweed at French Island. Sampling was performed in July 2024 (winter) and February 2025 (summer) at two sites: Barro Vermelho and French Beach. Specimen identification was based on morphological characteristics, and the specimens were preserved in the *Herbarium Dra. Tatiana U. P. Konno* (NUPEM/UFRJ). A total of 74 species were identified, distributed among Rhodophyta (44), Chlorophyta (20), and Heterokontophyta (10). The order Ceramiales was the most representative, composed mainly of epiphytes. Among green algae, Bryopsidales and Cladophorales showed the highest representativeness. *Caulerpa ambigua* is reported for the first time along the northern coast of Rio de Janeiro, thereby expanding its geographic range within the state. The environmental and structural differences between the two sites likely contributed to the higher species richness (64 taxa) observed at French Beach. Summer was also the season with the highest number of species (47 and 69), which was more conducive to their growth. These findings support conservation efforts, environmental monitoring, and future research in Macaé.

Keywords: Biodiversity; Conservation; Chlorophyta; Heterokontophyta; Rhodophyta; Taxonomy

1 Introduction

Macroalgae are biologically and ecologically important components of aquatic ecosystems (Williams and Smith 2007), as they constitute the primary producers in these environments (Bothwell 2023). In addition, they provide shelter, substrate, and food resources for a wide variety of marine organisms (Coutinho and Zalmon 2009) and may also function as bioindicators of environmental disturbances (Figueiredo et al. 2004). Therefore, it is understandable that any factor affecting macroalgal communities may have cascading effects on organisms occupying higher trophic levels (Mejia et al. 2012). Beyond their considerable ecological significance, these organisms are also widely used as raw materials in the production of industrial products (Pedrini 2010; 2011).

In Brazil, researchers have described approximately 900 species of benthic seaweeds (Flora e Funga do Brasil 2026). This high level of diversity has motivated a wide range of studies that use macroalgae as either model organisms or primary research subjects, encompassing topics from their economic applications (Wan et al. 2019; Kammler et al. 2024) to taxonomic investigations (Manoylov 2014). However, most studies about the Brazilian marine flora focused continental coastal regions or oceanic islands in northeastern Brazil (Pedrini et al. 1992; Cunha et al. 2013). In the state of Rio de Janeiro, research efforts have predominantly focused on mainland coastal areas, ranging from the southern coast (Brito et al. 2002; Figueiredo et al. 2004) to municipalities in the Baixada Litorânea region and the Cabo Frio area (Yoneshigue 1985; Guimaraens and Coutinho 1996; Guimaraens et al. 2008), as well as the northern portion of the state (Yoneshigue-Valentin et al. 2008; Brasileiro et al. 2009). Nevertheless, phycological studies conducted on the state's islands have largely been restricted to southern Rio de Janeiro, whereas the islands in the northern portion remains comparatively understudied and lacks such information (Széchy 2015).

The Santana Archipelago (Arquipélago de Santana) belongs to the municipality of Macaé, in the northern region of Rio de Janeiro state, and is notable for being the northernmost island group along the coast of Rio de Janeiro. Since December 16, 1989, the archipelago has been designated as an Environmental Protection Area (Área de Proteção Ambiental, APA) under Municipal Law No. 1216/1989. The area is of considerable importance to the municipality, both for its touristic potential and for its remarkable biodiversity, including birds (Alves 1993; Costa and Mancini 2024), bivalves (Oliva 2008), and fish (Bauer et al. 2017). Nevertheless, its macroalgal flora remains largely unexplored, with no specific studies having been conducted to date. According to Machado, Nassar, and Széchy (2011), the lack of knowledge regarding

seaweed diversity constitutes one of the major obstacles to the development of effective conservation strategies.

As an Environmental Protection Area (Área de Proteção Ambiental, APA), the Santana Archipelago allows sustainable touristic activities in its surrounding waters, particularly on French Island (Ilha do Francês). However, the lack of effective supervision has resulted in tourism becoming increasingly intense and environmentally predatory. Furthermore, the archipelago is situated approximately 8 km from the Engenheiro Zephyrino Lavenère Machado Filho Port, which is located at Imbetiba Beach. This port serves as a logistical support base for oil exploration and extraction operations in the Campos Basin (Petrobras 2024). In addition, the archipelago lies within the direct area of influence of the upcoming Offshore Terminal B of the Macaé Port Terminal (TEPOR) (Tepor 2018). It is relevant to note that, to facilitate the implementation of the TEPOR project, the government of Macaé reduced the buffer zone of the Santana Archipelago APA from 16 km to 4 km through Municipal Law No. 4,349/2017, arguing that the TEPOR development would serve as a significant source of employment for the local population (Pinheiro and Arruda 2023). This suggests that any accidents associated with these industrial enterprises could have substantial impacts on the fauna and flora of this protected area (Absalão and Pimenta 2005).

In this context, the vulnerability of the Santana Archipelago's biodiversity to environmental impacts becomes evident, thereby reinforcing the need for baseline studies on benthic marine macroalgae. The documentation and cataloging of the species occurring within the Santana Archipelago Environmental Protection Area (APA) are essential, as such knowledge will provide valuable information for ecological research, environmental monitoring, sustainable management practices, and, consequently, the long-term conservation of this protected area.

2 Material and methods

Study area and sampling

The Santana Archipelago covers an area of approximately 1.8 km² and is located 8 km offshore from the municipality of Macaé, at coordinates 22°24′33.4″ S and 41°42′07.7″ W. It comprises four main islands, namely Santana Island (Ilha de Santana), French Island (Ilha do Francês), Mackerel's End (Ponta das Cavalas), and Southern Islet (Ilhote Sul), as well as several rocky outcrops, such as the Cruet's End (Ponta da Galheta), and submerged reefs (Fig. 1). French Island (22°24′05.7″ S; 41°41′36.6″ W) is also situated

approximately 8 km from the mainland coast. Although jurisdiction over the island falls under the authority of the Brazilian Navy, access is permitted without prior authorization and can be readily achieved by boat. In contrast, Santana Island (22°24′42″ S; 41°42′17″ W), which is likewise under Navy administration, may only be accessed upon prior notification and subject to authorization by the responsible naval authorities.

Two biological sampling campaigns were conducted, one during the winter season (July 2024) and the other during the summer season (February 2025). Two sampling sites were selected on French Island: (1) Red Clay (Barro Vermelho) (22°24′05″ S; 41°41′30″ W) and (2) French Beach (Praia do Francês) (22°24′07″ S; 41°41′44″ W) (Fig. 1). Samples were collected through unrestricted manual scraping during low tide periods (Nunes 2010). Following collection, the material was transported to the Integrated Marine Biology Laboratory (LIBMar) at the Institute of Biodiversity and Sustainability (NUPEM/UFRJ) for further processing and analysis.

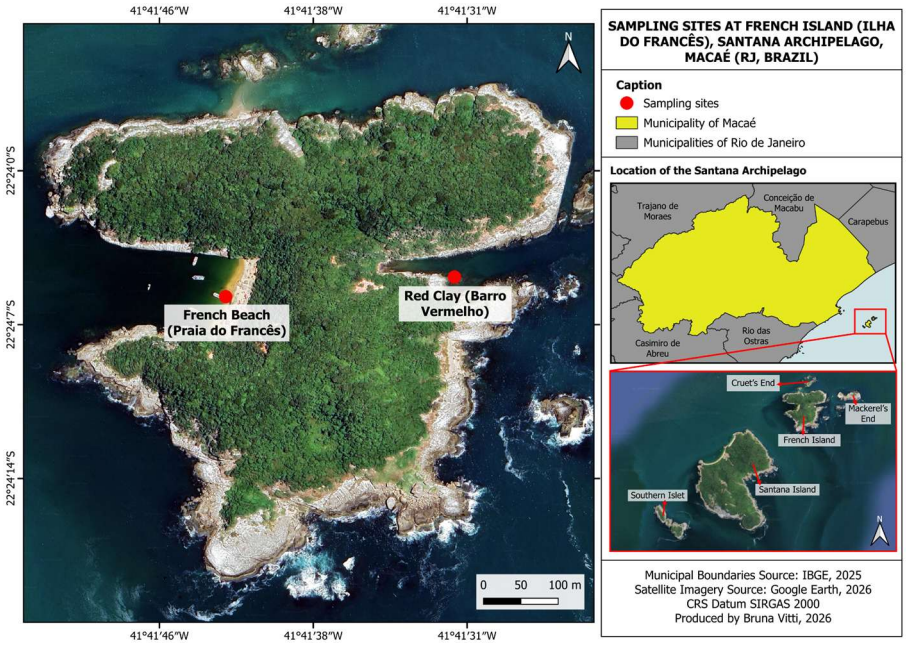


Fig. 1 View of the sampling sites on French Island (Red Clay, or Barro Vermelho, and French Beach) and the islands forming the Santana Archipelago: Mackerel's End (Ponta das Cavalas), Cruet's End (Ponta da Galheta), French Island, Santana Island and Southern Islet (Ilhote Sul).

In addition to the collections conducted for this study on French Island, all historical seaweed records from the Santana Archipelago deposited in the Herbarium Dra. Tatiana U. P. Konno (NUPEM/UFRJ) were examined. These records, originating from different sampling campaigns over the years since 2006, were compiled to produce a comprehensive floristic inventory for the region, thereby contributing to a broader understanding of local macroalgal diversity. All retrieved records were incorporated into the final species list (Table 1).

Taxonomic identification

Identification of specimens was based on morphological characters. General features were examined under a Nikon stereomicroscope, whereas specific structures were analyzed using a Nikon Eclipse E-100 optical microscope. Semipermanent slides were prepared with 50% glycerin, containing thallus fragments sectioned transversely or observed in surface view (Nunes 2010). This procedure also facilitated the identification of epiphytic algae. Following microscopic examination, specimens were identified using artificial taxonomic keys. Nomenclature and taxonomic criteria followed the revision proposed by Guiry and Guiry (2026).

Deposit in Herbarium Collection

All identified specimens were deposited in the phycological collection in the *Herbarium Dra. Tatiana U. P. Konno* (NUPEM/UFRJ).

3 Results

A total of 74 species were collected in the French Island. Rhodophyta was the most representative phylum, comprising 45 species (59%), followed by Chlorophyta with 20 species (27%) and Heterokontophyta with ten species (14%) (Fig. 2). Within each phylum, the most species-rich orders were Ceramiales (Rhodophyta), with 20 species; Bryopsidales and Cladophorales (Chlorophyta), each with nine species; and Ectocarpales (Heterokontophyta), with four species.

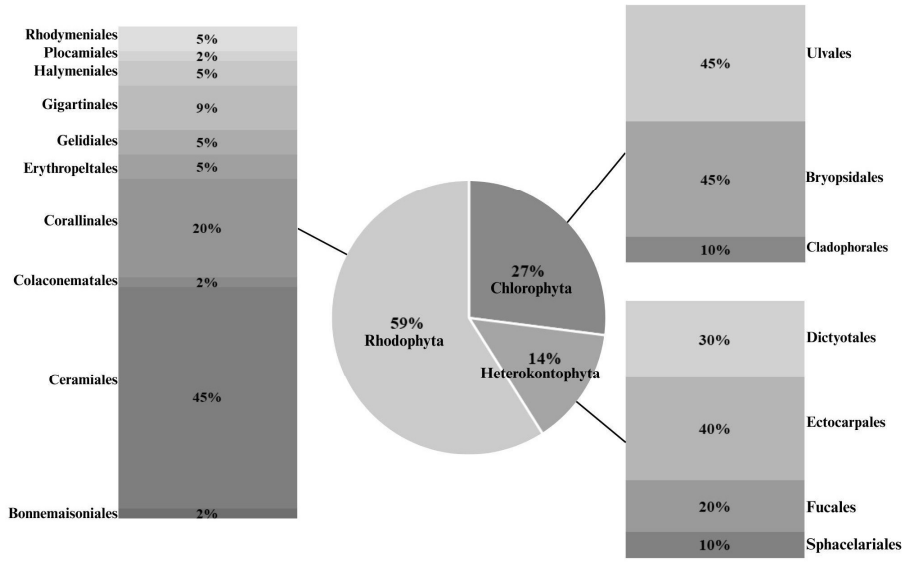


Fig. 2 Percentage distribution by phylum and order for each seaweed collected at French Island. Values reflect the representation of each group relative to the total species found

Highest species richness was recorded at French Beach in both sampling periods, in a total of 69 species, whereas Red Clay comprised 48 species (Fig. 3). French Beach also exhibited the highest number of exclusive species, with 27 records, while Red Clay had only six exclusive species.

The summer collection (February 2024) registered a higher number of species at both sites: 43 species at Red Clay and 64 species at French Beach. In contrast, the winter collection (July 2025) showed reduced species richness, with 32 species at Barro Vermelho and 54 species at French Beach (Fig. 3).

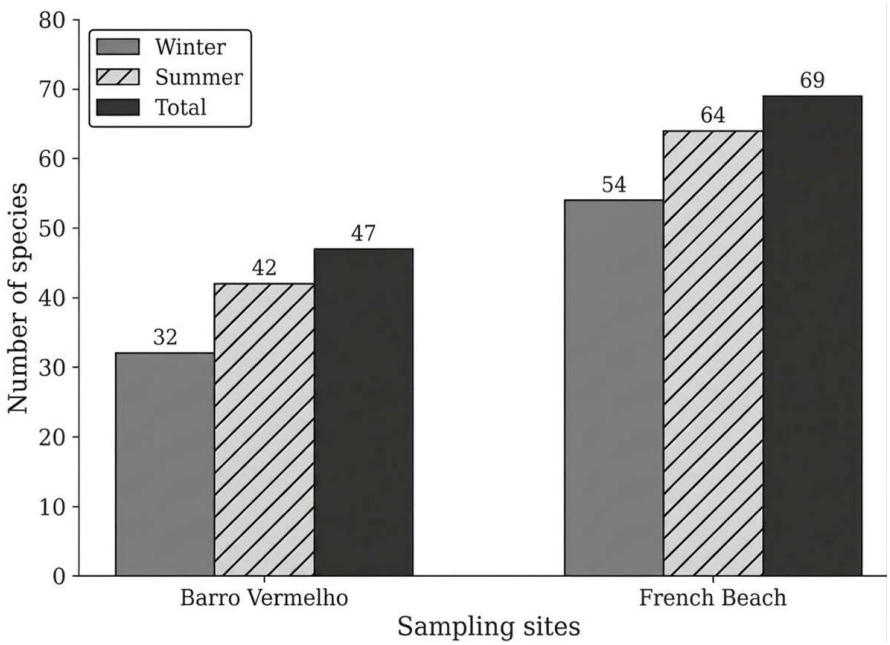


Fig. 3 Total number of species recorded at each sampling site (Barro Vermelho/Red Clay and Praia do Francês/French Beach), and total number of species recorded during the collecting periods (winter and summer) at each sampling site

Considering the recently collected samples and the analyzed Herbarium vouchers, a total of 115 species are reported across the Santana Archipelago (Table 1). A total of 41 specimens were only found in the Herbarium vouchers.

Synopsis of recorded taxa

Table 1 Distribution of taxa recorded in the Santana Archipelago relative to the sampling sites from this study and the herbarium record survey

	Ilha do Francês/French Island						Santana Island	Ponta da Galheta/ Cruet's End	Santana Archipelago
	Barro Vermelho/Red Clay			Praia do Francês/French Beach			Santana Beach	Unspecified	Unspecified
Taxon	**Winter 07/2024**	**Summer 02/2025**	**Herbarium voucher**	**Winter 07/2024**	**Summer 02/2025**	**Herbarium voucher**	**Herbarium voucher**	**Herbarium voucher**	**Herbarium voucher**
Acinetospora crinita (Carmichael) Sauvageau	-	-	-	-	-	-	+	-	-
Acrochaetium sp.	-	-	-	-	-	-	-	-	+
Aglaothamnion sp. *	-	-	-	-	+	-	+	-	-
Amphiroa sp. *	+	+	+	+	+	-	+	-	-
Arthrocardia flabellata * (Kützing) Manza	+	+	-	+	+	-	+	-	-
Arthrocardia sp. 1 *	-	+	-	-	+	-	+	-	-
Arthrocardia sp. 2	-	-	-	-	-	-	+	-	-
Arthrocardia sp. 3	-	-	-	-	-	-	-	+	-
Arthrocardia sp. 4	-	-	-	-	-	-	-	-	+
Asparagopsis taxiformis * (Delile) Trevisan	+	+	-	+	+	+	+	+	+
Asterocladon breviarticulatum (J.Agardh) E.Sasagawa, Uwai & Kogame	-	-	-	-	-	-	+	-	-
Bachelotia antillarum (Grunow) Gerloff	-	-	-	-	-	-	-	-	+
Bryocladia itaipensis J.O.F.Brito & Cassano	-	-	-	-	-	-	+	-	-

+: at least one specimen present; -: specimen absent at the site; *: species recorded during July 2024 and February 2025 sampling on French Island. The remaining species were located at the Dra. Tatiana U. P. Konno Herbarium (NUPEM/UFRJ) records.

Table 1 (continued)

Taxon	Ilha do Francês/French Island						Santana Island	Ponta da Galheta/ Cruet's End	Santana Archipelago
	Barro Vermelho/Red Clay			Praia do Francês/French Beach			Santana Beach	Unspecified	Unspecified
	Winter 07/2024	Summer 02/2025	Herbarium voucher	Winter 07/2024	Summer 02/2025	Herbarium voucher	Herbarium voucher	Herbarium voucher	Herbarium voucher
Bryocladia subtilissima * (Montagne) Díaz-Tapia	-	-	-	+	+	+	-	-	+
Bryopsis pennata * J.V.Lamouroux	+	+	-	+	+	-	+	-	+
Bryopsis plumosa (Hudson) C.Agardh	-	-	-	-	-	-	-	+	-
Canistrocarpus cervicornis (Kützing) De Paula & De Clerck	-	-	-	-	-	-	-	-	+
Caulerpa ambigua * Okamura	+	+	-	+	+	-	+	-	-
Caulerpa racemosa var. *macrophysa (*Sonder ex Kützing) W.R.Taylor	-	-	-	-	-	+	-	-	-
Centroceras gasparrinii * (Meneghini) Kützing	-	+	-	+	+	-	+	-	-
Centroceras hyalacanthum * Kützing	-	+	-	+	+	-	+	-	-
Centroceras sp.	-	-	-	-	-	+	+	-	-
Ceramium sp. 1	-	-	-	-	-	-	+	+	-
Ceramium sp. 2	-	-	-	-	-	-	-	+	-
Chaetomorpha aerea (Dillwyn) Kützing	-	-	-	-	-	+	-	-	-
Chaetomorpha antennina * (Bory) Kützing	+	+	-	+	+	+	+	-	+

+: at least one specimen present; -: specimen absent at the site; *: species recorded during July 2024 and February 2025 sampling on French Island. The remaining species were located at the Dra. Tatiana U. P. Konno Herbarium (NUPEM/UFRJ) records.

Table 1 (continued)

	Ilha do Francês/French Island						Santana Island	Ponta da Galheta/ Cruet's End	Santana Archipelago
	Barro Vermelho/Red Clay			Praia do Francês/French Beach			Santana Beach	Unspecified	Unspecified
Taxon	**Winter 07/2024**	**Summer 02/2025**	**Herbarium voucher**	**Winter 07/2024**	**Summer 02/2025**	**Herbarium voucher**	**Herbarium voucher**	**Herbarium voucher**	**Herbarium voucher**
Chaetomorpha brachygona * Harvey	-	+	-	-	-	-	-	-	-
Chaetomorpha sp. 1 *	+	-	-	-	-	-	-	-	-
Chaetomorpha sp. 2 *	+	-	-	-	-	-	-	-	-
Champia compressa * Harvey	+	+	-	+	+	-	-	-	-
Chondracanthus saundersii * C.W.Schneider & C.E.Lane	+	+	-	+	+	-	+	-	-
Chondria atropurpurea Harvey	-	-	-	-	-	-	+	-	-
Chondria polyrhiza Collins & Hervey	-	-	-	-	-	-	-	-	+
Cladophora laetevirens * (Dillwyn) Kützing	-	+	-	+	+	-	-	-	-
Cladophora prolifera * (Roth) Kützing	-	-	-	+	+	+	-	-	-
Cladophora vagabunda * (Linnaeus) C.Hoek	-	-	-	+	+	+	-	-	+
Cladophoropsis membranacea * (Bang ex C.Agardh) Børgesen	-	+	+	+	+	+	+	-	+
Cladophora sp.	-	-	-	-	-	-	+	-	-

+: at least one specimen present; -: specimen absent at the site; *: species recorded during July 2024 and February 2025 sampling on French Island. The remaining species were located at the Dra. Tatiana U. P. Konno Herbarium (NUPEM/UFRJ) records.

Table 1 (continued)

Taxon	Ilha do Francês/French Island						Santana Island	Ponta da Galheta/ Cruet's End	Santana Archipelago
	Barro Vermelho/Red Clay			Praia do Francês/French Beach			Santana Beach	Unspecified	Unspecified
	Winter 07/2024	Summer 02/2025	Herbarium voucher	Winter 07/2024	Summer 02/2025	Herbarium voucher	Herbarium voucher	Herbarium voucher	Herbarium voucher
Codium decorticatum * (Woodward) M.Howe	+	+	+	+	+	-	+	+	+
Codium intertextum * Collins & Hervey	-	+	-	+	-	+	+	-	-
Codium isthmocladum * Vickers	-	+	-	-	-	+	-	-	-
Codium sp.	-	-	-	-	-	-	-	-	+
Codium spongiosum * Harvey	-	-	-	+	-	+	+	+	+
Codium taylorii * P.C.Silva	+	+	-	+	+	+	+	+	-
Colaconema codicola * (Børgesen) Stegenga, J.J.Bolton & R.J.Anderson	+	+	-	-	+	-	+	-	-
Cryptonemia bengryi W.R.Taylor	-	-	-	-	-	+	+	-	-
Cryptonemia limensis * (Kützing) J.A.Lewis	+	-	-	+	+	-	+	-	-
Cryptonemia seminervis * (C.Agardh) J.Agardh	-	-	-	+	+	+	-	-	-
Cryptonemia sp.	-	-	-	-	-	-	+	-	-
Cryptopleura ramosa * (Hudson) L.Newton	-	-	-	-	+	-	+	-	-
Dasya brasiliensis * E.C.Oliveira Filho & Y.Y.Braga	-	-	-	-	+	+	+	-	-

+: at least one specimen present; -: specimen absent at the site; *: species recorded during July 2024 and February 2025 sampling on French Island. The remaining species were located at the Dra. Tatiana U. P. Konno Herbarium (NUPEM/UFRJ) records.

Table 1 (continued)

Taxon	Ilha do Francês/French Island						Santana Island	Ponta da Galheta/ Cruet's End	Santana Archipelago
	Barro Vermelho/Red Clay			Praia do Francês/French Beach			Santana Beach	Unspecified	Unspecified
	Winter 07/2024	Summer 02/2025	Herbarium voucher	Winter 07/2024	Summer 02/2025	Herbarium voucher	Herbarium voucher	Herbarium voucher	Herbarium voucher
Dasya corymbifera * J.Agardh	-	-	-	+	+	-	+	-	-
Derbesia marina * (Lyngbye) Solier	+	+	-	+	+	-	+	-	-
Derbesia sp.	-	-	-	-	-	-	-	+	-
Dictyopteris delicatula * J.V.Lamouroux	-	+	-	+	-	-	-	-	-
Dictyota caribaea Hörnig & Schnetter	-	-	-	-	-	+	-	-	-
Dictyota dichotoma * (Hudson) J.V.Lamouroux	+	+	-	+	+	-	+	-	-
Dictyota mertensii (Martius) Kützing	-	-	-	-	-	+	-	-	-
Dictyota sp.	-	-	-	-	-	-	-	-	+
Erythrotrichia carnea * (Dillwyn) J.Agardh	-	+	-	-	+	-	+	+	-
Gayliella dawsonii * (A.B.Joly) Barros-Barreto & F.P.Gomes	+	+	-	+	+	-	+	-	+
Gayliella flaccida * (Harvey ex Kützing) T.O.Cho & L.M.McIvor	+	+	-	+	+	-	-	-	-
Gelidium crinale (Hare ex Turner) Gaillon	-	-	-	-	-	-	+	-	-
Gelidium pusillum (Stackhouse) Le Jolis	-	-	-	-	-	-	-	-	+

+: at least one specimen present; -: specimen absent at the site; *: species recorded during July 2024 and February 2025 sampling on French Island. The remaining species were located at the Dra. Tatiana U. P. Konno Herbarium (NUPEM/UFRJ) records.

Table 1 (continued)

	Ilha do Francês/French Island						Santana Island	Ponta da Galheta/ Cruet's End	Santana Archipelago
	Barro Vermelho/Red Clay			Praia do Francês/French Beach			Unspecified	Unspecified	Unspecified
Taxon	**Winter 07/2024**	**Summer 02/2025**	**Herbarium voucher**	**Winter 07/2024**	**Summer 02/2025**	**Herbarium voucher**	**Herbarium voucher**	**Herbarium voucher**	**Herbarium voucher**
Gelidium sp. *	-	-	-	+	-	-	-	-	-
Gracilaria sp.	-	-	-	-	-	-	-	-	+
Gymnogongrus griffithsiae (Turner) Martius	-	-	-	-	-	+	+	-	-
Gymnothamnion elegans * (Schousboe ex C.Agardh) J.Agardh	-	-	-	+	-	-	-	-	-
Herposiphonia parca * Setchell	-	+	-	-	+	-	+	-	-
Herposiphonia secunda (C. Agardh) Ambronn	-	-	-	-	-	-	-	-	+
Herposiphonia tenella * (C. Agardh) Ambronn	-	+	-	+	+	+	+	-	+
Hildenbrandia prototypus Nardo	-	-	-	-	-	-	-	+	-
Hildenbrandia rubra (Sommerfelt) Meneghini	-	-	-	-	-	-	-	-	+
Hypnea cornuta * (Kützing) J.Agardh	-	-	-	-	+	-	-	-	-
Jania crassa J.V.Lamouroux	-	-	-	-	-	+	-	-	+
Jania pedunculata var. *adhaerens* (J.V.Lamouroux) A.S.Harvey, Woelkerling & Reviers	-	-	+	-	-	+	-	-	+

+: at least one specimen present; -: specimen absent at the site; *: species recorded during July 2024 and February 2025 sampling on French Island. The remaining species were located from the survey conducted at the Dra. Tatiana U. P. Konno Herbarium (NUPEM/UFRJ) records.

Table 1 (continued)

	Ilha do Francês/French Island						Santana Island	Ponta da Galheta/ Cruet's End	Santana Archipelago
	Barro Vermelho/Red Clay			Praia do Francês/French Beach			Santana Beach	Unspecified	Unspecified
Taxon	**Winter 07/2024**	**Summer 02/2025**	**Herbarium voucher**	**Winter 07/2024**	**Summer 02/2025**	**Herbarium voucher**	**Herbarium voucher**	**Herbarium voucher**	**Herbarium voucher**
Jania sp. 1 *	+	+	-	+	+	-	+	-	-
Jania sp. 2 *	+	+	-	+	+	-	+	-	-
Jania sp. 3 *	+	-	-	+	+	-	+	-	-
Jania sp. 4	-	-	-	-	-	-	-	+	-
Jania sp. 5	-	-	-	-	-	-	-	-	+
Jania ungulata (Yendo) Yendo	-	-	-	-	-	-	+	-	-
Laurencia dendroidea * J.Agardh	-	-	-	+	+	-	+	-	+
Laurencia obtusa (Hudson) J.V.Lamouroux	-	-	-	-	-	+	-	-	-
Levringia brasiliensis (Montagne) A.B.Joly	-	-	-	-	-	+	-	-	+
Melanothamnus sphaerocarpus * (Børgesen) Díaz-Tapia & Maggs	-	+	-	+	+	-	+	-	-
Neogoniolithon solubile * (Foslie & M.Howe) Setchell & L.R.Mason	+	+	-	-	+	-	-	-	-
Ophidocladus simpliciusculus (P.Crouan & H.Crouan) Falkenberg	-	-	-	-	-	-	+	-	-

+: at least one specimen present; -: specimen absent at the site; *: species recorded during July 2024 and February 2025 sampling on French Island. The remaining species were located at the Dra. Tatiana U. P. Konno Herbarium (NUPEM/UFRJ) records.

Table 1 (continued)

Taxon	Ilha do Francês/French Island						Santana Island	Ponta da Galheta/ Cruet's End	Santana Archipelago
	Barro Vermelho/Red Clay			Praia do Francês/French Beach			Santana Beach	Unspecified	Unspecified
	Winter 07/2024	Summer 02/2025	Herbarium voucher	Winter 07/2024	Summer 02/2025	Herbarium voucher	Herbarium voucher	Herbarium voucher	Herbarium voucher
Padina gymnospora * (Kützing) Sonder	-	-	-	+	+	+	-	-	-
Plocamium sp.	-	-	-	-	-	-	-	-	+
Pneophyllum fragile * Kützing	+	+	-	+	+	-	+	+	+
Porphyra sp.	-	-	-	-	-	-	+	-	-
Pterocladiella capillacea * (S.G.Gmelin) Santelices & Hommersand	-	-	-	+	+	+	+	+	+
Ptilothamnion speluncarum * (Collins & Hervey) D.L.Ballantine & M.J.Wynne	-	-	-	+	+	-	-	-	-
Rama rupestris (Linnaeus) Boedeker, M.J.Wynne & Zuccarello	-	-	-	-	-	-	-	-	+
Rhodymenia pseudopalmata * (J.V.Lamouroux) P.C.Silva	-	-	-	-	+	-	-	-	-
Sahlingia subintegra * (Rosenvinge) Kornmann	+	-	-	-	-	-	+	-	-
Sargassum cymosum C.Agardh	-	-	-	-	-	+	-	-	-
Sargassum furcatum * Kützing	-	-	-	-	+	-	-	-	-
Sargassum pacificum Bory	-	-	-	-	-	-	-	-	+

+: at least one specimen present; -: specimen absent at the site; *: species recorded during July 2024 and February 2025 sampling on French Island. The remaining species were located at the Dra. Tatiana U. P. Konno Herbarium (NUPEM/UFRJ) records.

Table 1 (continued)

	Ilha do Francês/French Island						Santana Island	Ponta da Galheta/ Cruet's End	Santana Archipelago
	Barro Vermelho/Red Clay			Praia do Francês/French Beach			Santana Beach	Unspecified	Unspecified
Taxon	**Winter 07/2024**	**Summer 02/2025**	**Herbarium voucher**	**Winter 07/2024**	**Summer 02/2025**	**Herbarium voucher**	**Herbarium voucher**	**Herbarium voucher**	**Herbarium voucher**
Sargassum vulgare * C.Agardh, nom. illeg.	-	-	+	-	+	+	-	-	-
Scinaia complanata (Collins) Cotton	-	-	-	-	-	-	+	-	-
Sphacelaria bracygonia * Montagne	-	-	-	+	+	-	+	-	-
Sphacelaria sp.	-	-	-	-	-	-	-	-	+
Ulva compressa Linnaeus	-	-	-	-	-	-	+	-	-
Ulva lactuca * Linnaeus	+	+	-	+	+	+	+	-	+
Ulva rigida C.Agardh	-	-	-	-	-	+	-	-	-
Ulva tepida * Masakiyo & S.Shimada	+	+	-	+	+	+	+	-	-
Vertebrata foetidissima * (Cocks ex Bornet) Díaz-Tapia & Maggs	-	-	-	+	+	-	+	-	-
Willeella brachyclados * (Montagne) M.J.Wynne	-	-	-	+	+	-	-	-	-
Wilsonosiphonia howei * (Hollenberg) D.Bustamante, Won & T.O.Cho	-	-	-	+	+	-	+	-	-
Wrangelia sp.	-	-	-	-	-	-	-	-	+

+: at least one specimen present; -: specimen absent at the site; *: species recorded during July 2024 and February 2025 sampling on French Island. The remaining species were located at the Dra. Tatiana U. P. Konno Herbarium (NUPEM/UFRJ) records.

Table 1 (continued)

	Ilha do Francês/French Island						Santana Island	Ponta da Galheta/ Cruet's End	Santana Archipelago
	Barro Vermelho/Red Clay			Praia do Francês/French Beach			Santana Beach	Unspecified	Unspecified
Taxon	**Winter 07/2024**	**Summer 02/2025**	**Herbarium voucher**	**Winter 07/2024**	**Summer 02/2025**	**Herbarium voucher**	**Herbarium voucher**	**Herbarium voucher**	**Herbarium voucher**
Wrangelia argus * (Montagne) Montagne	-	-	-	+	+	-	+	+	-
Xiphosiphonia pennata * (C.Agardh) Savoie & G.W.Saunders	-	-	-	+	+	-	-	-	-
Yoneshiguea compta * (Børgesen) Barros-Barreto, Maggs & M.A.Jaramillo	-	-	-	+	+	-	+	-	-

+: at least one specimen present; -: specimen absent at the site; *: species recorded during July 2024 and February 2025 sampling on French Island. The remaining species were located at the Dra. Tatiana U. P. Konno Herbarium (NUPEM/UFRJ) records.

4 Discussion

The results highlight the predominance of the phylum Rhodophyta, followed by Chlorophyta and Heterokontophyta, corroborating the patterns reported for algal flora composition in subtropical regions (Yoneshigue-Valentin et al. 2008; Kasanah et al. 2022). This distribution pattern among phyla is also consistent with observations for the Região dos Lagos (Lakes Region) and northern Rio de Janeiro state (Brasileiro et al. 2009; Almeida et al. 2025).

The success of red seaweeds results from a combination of adaptive strategies, including complex life cycles, high reproductive plasticity, and tolerance to environmental stressors (Chen et al. 2022; Krueger-Hadfield et al. 2024). These algae thrive in diverse environments due to their epizoic, epilithic, and epiphytic life forms (Mendoza-González et al. 2011). Results revealed the predominance of the order Ceramiales, with most identified species exhibiting an epiphytic habit, underscoring the broad diversity within this group.

Green seaweed exhibited greater visual coverage on the rocky shores compared with the other phyla. Members of Bryopsidales were particularly prominent, showing extensive substrate cover, especially *Caulerpa* spp., a pattern consistently reported along the Brazilian coast (Horta et al. 2001) and in other subtropical regions (Kerswell 2006). In contrast, French Beach showed a high frequency of Cladophorales in both sampling periods, which may be associated with increased mechanical stress at this site. Strong local hydrodynamics, combined with tourist activities, promote recurrent removal of macroalgae from the rocky shores and create open substrate patches available for recolonization. In this context, Cladophorales species — recognized as opportunistic due to their high growth rates and rapid occupation of disturbed spaces — tend to colonize newly available substrates quicker, thereby limiting the establishment of slower-growing species with lower competitive capacity (Barbosa et al. 2008).

Caulerpa ambigua was recorded for the first time in the northern coast of Rio de Janeiro state. Until now, this species had only been reported from the municipality of Angra dos Reis, on the southern coast of the state, by Gestinari, Nassar and Arantes (1998), and by Mitchell et al. (1979) under the name *Caulerpa vickersiae*. The material examined also agrees with descriptions of *Caulerpa ambigua* provided by Széchy et al. (1987), Pereira and Accioly (1998), and Oliveira-Carvalho et al. (2003) for the state of Pernambuco; Kanagawa (1983) for Paraíba; and Pedrini et al. (1989) for Espírito Santo. In addition, it corresponds to the description of *Caulerpella ambigua* by Coto and Pupo (2009) for São Paulo. All authors describe the species as uncommon across sampled sites, corroborating the findings of the present study. It is worth noting that most collection sites reported in previous studies are located in insular environments, such as Fernando de Noronha (PE), Ilha da Trindade (ES), and Ilha

Grande (RJ) (Széchy et al. 1987; Pedrini et al. 1989; Gestinari et al. 1998), or in reef areas adjacent to islands (Pereira and Accioly 1998; Oliveira-Carvalho et al. 2003). The occurrence of *Caulerpa ambigua* on French Island indicates a distribution pattern in Brazil strongly associated with insular habitats. This record expands the known range of the species to include the northern region of Rio de Janeiro.

The low presence of brown seaweed may be attributed to the sampling method employed, as free-hand scraping depends on tidal variation for specimen collection. Species commonly found in the infralittoral zone, including most brown algae, are more difficult to sample using this approach. Among the recorded species, the genus *Sargassum* is recognized for its biotechnological relevance (Santos et al. 2023). In addition, several studies have investigated other taxa — such as *Colpomenia sinuosa*, *Chnoospora minima*, *Dictyopteris delicatula*, *Padina gymnospora*, and representatives of *Dictyota* — regarding their potential as producers of bioactive compounds of medical and agricultural interest (Fernandes et al. 2014; Zafar et al. 2022).

Most specimens identified only at the genus level could not be determined to species due to the scarcity or small size of the available material. The exception are the calcified red algae *Amphiroa* sp., *Arthrocardia* sp., *Corallina* sp., *Jania* sp. 1, *Jania* sp. 2, and *Jania* sp. 3, whose identification was limited by the high occurrence of cryptic species, the scarcity of taxonomic studies based on morphological characters, and the outdated nature of available identification keys. These constraints suggest that some specimens may represent undescribed species. Therefore, molecular analyses are required to confirm the taxonomic identity of these organisms and to assess the possible occurrence of novel species in the study area.

The greater number of taxa recorded at French Beach may be related to geological differences and to the structure of the rocky shores at the sampled sites. Local ecological conditions also directly influence the composition and structure of macroalgal communities (Mendoza-González et al. 2011). Notably, sediment composition differs markedly between the two beaches: at French Beach, the substrate consists predominantly of coarse sand, whereas at Red Clay a fine, reddish clay predominates, as suggested by the site's name. Particle size can directly affect seaweed communities by determining which species are able to establish at each location (Harlin and Linderbergh 1977).

At French Beach, a high diversity of species associated with the mineral substrate was observed, whereas at Red Clay calcareous algae growing directly on the sediment were predominant. This may restrict the growth and diversity of other species and require colonization of alternative substrates. Calcareous algae tend to be more abundant and better developed in areas with higher environmental quality and lower levels of disturbance

(Schoenrock et al. 2018), suggesting that the impact of tourist activities at French Beach may reduce their occurrence and, consequently, create opportunities for the establishment of other species.

A higher number of species was recorded in summer, indicating a clear seasonal pattern in macroalgal occurrence. This variation may be associated with changes in environmental conditions throughout the year, as factors such as light availability, water temperature, humidity, precipitation, and nutrient supply modulate abundance and diversity on rocky shores (Cruz-Motta et al. 2010; Ojeda et al. 2019). During summer, increases in temperature and precipitation may favor the growth of several taxa, including *Cladophora* spp., *Codium* spp., *Dictyota* sp., *Sargassum* spp., *Dasya* spp., and various Rhodomelaceae (Ferrari et al. 2012; Ojeda et al. 2019). However, some species were more persistent over time, occurring in both sampling periods, such as *Bryopsis* spp., *Caulerpa* spp., *Chaetomorpha* spp., *Derbesia* sp., *Feldmannia* spp., most Corallinaceae, *Champia* sp., *Chondracanthus* sp., and *Plocamium* sp. This seasonal pattern has been documented in other regions, corroborating the results obtained here (Fulton et al. 2014).

In the study conducted by Yoneshigue-Valentin et al. (2008) at Cavaleiros Beach, also located in Macaé, 118 taxa were reported, whereas the present study recorded 74 taxa at French Island, and 115 taxa in the entirety of the Santana Archipelago. Of these, 37 were shared between collections, indicating that these species are typical of the Macaé region and have persisted over the past 18 years. In total, 54 species are shared between locations, suggesting that these species may be common in the area. In addition, 28 taxa collected in this study and 14 Herbarium voucher species encountered were not cited by Yoneshigue-Valentin et al. (2008), thereby contributing to the expansion of the regional species list.

The taxonomic survey of seaweed from the Santana Archipelago expands the floristic knowledge of Macaé and provides a basis for ecological, biotechnological, and biodiversity conservation research in the region. The differences observed among sampling sites indicate the need for site-specific management strategies, and the occurrence of cryptic species reinforces the importance of molecular analyses to confirm potential new taxa. The taxa recorded here do not represent the full extent of the Santana Archipelago macroalgal diversity, and additional samplings in the other islands are required for a more comprehensive understanding of the region's marine flora.

Acknowledgements

The authors wish to express their gratitude to the Federal University of Rio de Janeiro (UFRJ) and the Integrated Marine Biology Laboratory (LibMar/NUPEM) for providing logistical support; and to the Conselho Nacional de

Desenvolvimento Científico e Tecnológico (CNPq) for the scientific initiation scholarship granted to the first and third authors.

Author contributions

BSV — Conceptualization, data curation, identification, analysis, and writing. RMO — Supervision, data curation, and writing — review and editing. ALS — Data curation and writing. GOA — Supervision and data curation. LMSG — Conceptualization, supervision and writing — review and editing.

Declarations

Funding This study was funded by Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) through the Programa Institucional de Bolsas de Iniciação Científica (PIBIC), grant number 160559/2024-3 and 170440/2025-7.

Competing interests The authors have no competing interests to declare that are relevant to the content of this article.

References

Absalão RS, Pimenta AD (2005) Moluscos marinhos da APA do Arquipélago de Santana, Macaé, RJ: chave ilustrada para identificação das espécies do substrato inconsolidado. Ciência Moderna Ltda, Rio de Janeiro

Almeida GO, Oliveira RM, Vitti BS, Costa WS, Gestinari LMS (2025) Macroalgas marinhas de Barra de São João (Casimiro de Abreu): contribuição para o conhecimento da diversidade bentônica dos costões rochosos da baixada litorânea. IN: Medeiros MHT (org). Conservação da Biodiversidade: Estratégias para Proteger o Planeta 1st edn. Científica Digital, 1:37-54. https://doi.org/10.37885/241017941

Alves VS (1993) Aves do arquipélago de Santana e litoral continental adjacente Macaé - Rio de Janeiro, Brasil. Dissertation, Federal University of Rio de Janeiro

Barbosa SO, Figueiredo MAO, Testa V (2008) Estrutura e dinâmica de comunidades bentônicas dominadas por macrófitas na zona intramareal da Praia de Jacaraípe, Espírito Santo, Brasil. Hoehnea, 35(4):563-575. https://doi.org/10.1590/S2236-89062008000400008

Bauer AB, Fischer LG, Di Dario F, Mincarone MM (2017) Marine fishes (Elasmobranchii and Teleostei) from the Santana Archipelago, a Marine Protected Area in the southwestern Atlantic. Marine Biology Research, 13(8):813 - 831. https://doi.org/10.1080/17451000.2017.1302090

Bothwell JH (2023) Seaweeds of the World: A Guide to Every Order. Princeton University Press, Princeton Oxford

Brasileiro PS, Yoneshigue-Valentin Y, Bahia RG, Reis RP, Filho GMA (2009) Algas marinhas bentônicas daregião de Cabo Frio e arredores: síntese do conhecimento. Rodriguésia 60(1):39-66. https://doi.org/10.1590/2175-7860200960103

Brito LVR, Széchy MTM, Cassano V (2002). Levantamento Taxonômico das Macroalgas da Zona das Marés de Costões Rochosos Adjacentes ao Terminal Marítimo Almirante Maximiano Fonseca,Baía da Ilha Grande, RJ. Atlântica, 24(1):17-26

Chen H, Chu JSC, Chen J, Luo Q, Wang H, Lu R, Zhu Z, Yuan G, Yi X, Mao Y, Lu C, Wang Z, Gu D, Jin Z, Zhang X, Weng Z, Li S, Yan X, Yang R (2022) Insights into the Ancient Adaptation to Intertidal Environments by Red Algae Based on a Genomic and Multiomics Investigation of Neoporphyra haitanensis. Molecular Biology and Evolution, 39(1):1-18. https://doi.org/10.1093/molbev/msab315

Costa LN, Mancini PL (2024) Aves marinhas do arquipélago de Santana, Macaé (RJ). Editora Nupem, Macaé

Coutinho R., Zalmon IR (2009) Bentos de costões rochosos. In: Pereira RC, Soares-Gomes A (org) Biologia Marinha, 2nd edn. Interciência, Rio de Janeiro, pp 281-297

Cruz-Motta JJ, Miloslavich P, Palomo G, Iken K, Konar B, Pohle G, Trott T, Benedetti-Cecchi L, Herrera C, Hernández A, Sardi A, Bueno A, Castillo J, Klein1 E, Guerra-Castro E, Gobin J, Gómez DI, Riosmena-Rodríguez R, Mead A, Bigatti G, Knowlton A, Shirayama Y (2010) Patterns of Spatial Variation of Assemblages Associated with Intertidal Rocky Shores: A Global Perspective. PLoS ONE, 5(12):1-10. https://doi.org/10.1371/journal.pone.0014354

Cunha TJ, Güth AZ, Bromberg S, Sumida PYG (2013). Macrofauna associated with the brown algae Dictyota spp. (Phaeophyceae, Dictyotaceae) in the Sebastião Gomes Reef and Abrolhos Archipelago, Bahia, Brazil. Continental Shelf Research, 70:140-149. https://doi.org/10.1016/j.csr.2013.09.001

Ferrari R, Gonzalez-Rivero M, Ortiz JC, Mumby PJ (2012) Interaction of herbivory and seasonality on the dynamics of Caribbean macroalgae. Coral Reefs 31:683–692. https://doi.org/10.1007/s00338-012-0889-9

Fernandes DRP, Oliveira VP, Yoneshigue-Valentin Y (2014) Seaweed biotechnology in Brazil: six decades of studies on natural products and their antibiotic and other biological activities. Journal of Applied Phycology, 26:1923–1937. https://doi.org/10.1007/s10811-014-0287-5

Figueiredo OAM, Barreto BBM, Reis PR (2004) Caracterização das macroalgas nas comunidades marinhas da Área de Proteção Ambiental de Cairuçú, Parati, RJ – subsídios para futuros monitoramentos. Brazilian Journal of Botany, 27(1). https://doi.org/10.1590/S0100-84042004000100002

FLORA E FUNGA DO BRASIL. Jardim Botânico do Rio de Janeiro. Algas. Disponível em: https://floradobrasil.jbrj.gov.br/consulta/#CondicaoTaxonCP. Acesso em: 30 de jul. 2026

Fulton CJ, Depczynski M, Holmes TH, Noble MM, Radford B, Wernberg T, Wilson SH (2014) Sea temperature shapes seasonal fluctuations in seaweed biomass within the Ningaloo coral reef ecosystem. Limnology and Oceanography, 59(1):156-166. https://doi.org/10.4319/lo.2014.59.1.0156

Gestinari LMS, Nassar CAG, Arantes PVS (1998) Algas marinhas bentônicas da Reserva Biológica Estadual da Praia do Sul, Ilha Grande, Angra dos Reis, Rio de Janeiro, Brasil. Acta Botanica Brasilica, 12(1):67-76. https://doi.org/10.1590/S0102-33061998000100005

Guimaraens MA, Coutinho R (1996) Spatial and temporal variation of benthic marine algae at the Cabo Frio upwelling region, Rio de Janeiro, Brazil. Aquatic Botany, 52(4):283-299. https://doi.org/10.1016/0304-3770(95)00511-0

Guimaraens MA, Gonçalves JEA, Lourenço SO, Coutinho R (2008) Sensitivity analyses of population biomass dynamics for Ulva spp. and Sargassum furcatum at the Cabo Frio upwelling region of Brazil. Journal of Biological Systems, 16(4):579-596. https://doi.org/10.1142/S0218339008002629

Guiry MD, Guiry GM (2026) 04 August 2026. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway

Harlin MM, Lindbergh JM (1977) Selection of substrata by seaweeds: optimal surface relief. Marine Biology, 40(1):33-40

Horta PA, Amancio E, Coimbra CS, Oliveira EC (2001) Considerações sobre a distribuição e origem da flora de macroalgas marinhas brasileiras. Hoehnea, 28(3):243-265

Kammler S, Romero AM, Burkhardt C, Baruth L, Antranikian G, Liese A, Kaltschmitt M (2024) Macroalgae valorization for the production of polymers, chemicals, and energy. Biomass and Bioenergy, 183. https://doi.org/10.1016/j.biombioe.2024.107105

Kanagawa AI (1984) Clorofíceas marinhas bentônicas do estado da Paraíba. Dissertation, University of São Paulo

Kasanah N, Ulfah M, Imania O, Hanifah AN, Marjan MID (2022) Rhodophyta as Potential Sources of Photoprotectants, Antiphotoaging Compounds, and Hydrogels for Cosmeceutical Application. Molecules, 27: 2-26. https://doi.org/10.3390/molecules27227788

Kerswell AP (2006) Global biodiversity patterns of benthic marine algae. Ecology, 87(10):2479-2488. 10.1890/0012-9658(2006)87[2479:gbpobm]2.0.co;2

Krueger-Hadfield SA, Shainker-Connelly SJ, Crowell RM, Vis ML (2024) The eco-evolutionary importance of reproductive system variation in the macroalgae: Freshwater reds as a case study. Journal of Phycology, 60(1):15–25. https://doi.org/10.1111/jpy.13407

Manoylov KM (2014) Taxonomic identification of algae (morphological and molecular): species concepts, methodologies, and their implications for ecological bioassessment. Journal of Phycology, 50: 409-424. https://doi.org/10.1111/jpy.12183

Machado MEG, Nassar GAC, Széchy MTM (2011) Flora ecológica da região sublitorânea rasa de costões rochosos do Núcleo Picinguaba, Parque Estadual da Serra do Mar, Ubatuba, São Paulo. Acta Botanica Brasilica, 25(1):71-82. https://doi.org/10.1590/S0102-33062011000100010

Mejia AY, Puncher GN, Engelen AH (2012) Macroalgae in Tropical Marine Coastal Systems. In: Wiencke C, Bischof K (ed) Seaweed Biology. Ecological Studies, vol 219. Springer, Berlin, Heidelberg

Mendoza-González AC, Mateo-Cid LE, Galicia-García C (2011). Integración florística de las algas marinas de la costa sur de Jalisco, México. Revista Mexicana De Biodiversidad, 82(1):19-49. https://doi.org/10.22201/ib.20078706e.2011.1.383

Mitchell GJP, Széchy MTM, Mitsuya LA (1979) Sinopse das clorofíceas marinhas bentônicas do litoral do estado do Rio de Janeiro. Leandra, (8-9):91-123

Nunes JMC (2010) Taxonomia morfológica: metodologia de trabalho. In: Pedrini AG (ed) Macroalgas: Uma Introdução à Taxonomia. Flora Marinha do Brasil, 1st edn, vol 1. Technical Books, Rio de Janeiro

Ojeda J, Marambio J, Rosenfeld S, Contador T, Rozzi R, Mansilla A (2019) Seasonal changes of macroalgae assemblages on the rocky shores of the Cape Horn Biosphere Reserve, Sub-Antarctic Channels, Chile. Aquatic Botany, 157:33-41. https://doi.org/10.1016/j.aquabot.2019.06.001

Oliva MS (2008) Isolamento e identificação de bactérias potencialmente patogênicas a partir de bivalves no Arquipélago de Santana - Macaé, RJ. Dissertation, Federal Rural University of Rio de Janeiro

Oliveira-Carvalho MF, Pereira SMB, Zickel CS (2003) Florística e distribuição espaço-temporal das clorofíceas bentônicas em trechos recifais do litoral norte do estado de Pernambuco – Brasil. Hoehnea, 30(3):201-112

Pedrini AGD, Ugadim Y, Braga MRA, Pereira SMB (1992) Algas marinhas bentônicas do Arquipélago de Fernando de Noronha, Brasil. Boletim de Botânica, Univ. São Paulo, 13:93-101. https://doi.org/10.11606/issn.2316-9052.v13i0p93-101

Pedrini AG, Gonçalves JEA, Fonseca MCS, Zaú AS, Lacorte CCA (1989) Survey of the Marine Algae of Trindade Island, Brazil. Botanica Marina, 32:97-99.

Pedrini AG (1010) Macroalgas: uma introdução à taxonomia, 1st edn. Technical Books, Rio de Janeiro

Pedrini AG (2011) Macroalgas (Chlorophyta) e gramas (Magnoliophyta) marinhas do Brasil, 1st edn. Technical Books, Rio de Janeiro

Pereira SMB, Accioly MC (1998) Clorofíceas marinhas bentônicas da Praia de Serrambi, Pernambuco, Brasil. Acta Botanica Brasilica, 12(1):25-52. https://doi.org/10.1590/S0102-33061998000100003

PETROBRAS. Porto de Macaé, 2024. Disponível em: https://petrobras.com.br/quem somos/porto-de-macae. Acesso em: 30 set. 2024

Pinheiro RP, Arruda APSN (2023) Cidade e porto na economia do petróleo: Análise do novo terminal portuário de Macaé/RJ. Petróleo, Royalties e Região, 18(67):13-28

Santos TC, Vale TM, Cavalcanti DN, Machado LP, Barbarino E, Martins RCC, Obando JMC (2023) Metabólitos Bioativos e Aplicações Biotecnológicas de Macroalgas do Gênero Sargassum: Uma Revisão. Revista Virtual de Química, 15(4):741-758. https://doi.org/10.21577/1984-6835.20220125

Schoenrock KM, Bacquet M, Pearce D, Rea B, Schofield J, Lea J, Mair D, Kamenos N (2018) Influences of salinity on the physiology and distribution of the Arctic coralline algae, Lithothamnion glaciale (Corallinales, Rhodophyta). Journal of Phycology, 54(5). https://doi.org/10.1111/jpy.12774

Széchy MTM, Maurat MCS, Nassar CAG, Falcão C (1987) Adições à flora marinha bentônica do Arquipélago de Fernando de Noronha, 2nd edn. Nerítica, Pontal do Sul, pp 135-146

Széchy MTM (2015) Macroalgas marinhas da área de influência da Central Nuclear Almirante Álvaro Alberto – Baía da Ilha Grande/Rio de Janeiro. Eletronuclear, Rio de Janeiro

TEPOR. Relatório de Impacto Ambiental – RIMA: Projeto Terminal Portuário de Macaé (TEPOR). Macaé, Rio de Janeiro, 2018. Disponível em: https://www.inea.rj.gov.br/eia-rima 2018/. Acesso em: 30 mar. 2026

Wan AHL., Davies SJ, Soler-Vila A, Fitzgerald R, Johnson MP (2019), Macroalgae as a sustainable aquafeed ingredient. Reviews in Aquaculture, 11:458-492. https://doi.org/10.1111/raq.12241

Williams SL, Smith JE (2007) A Global Review of the Distribution, Taxonomy, and Impacts of Introduced Seaweeds. Annual Review of Ecology, Evolution, and Systematics 38:327-359. https://doi.org/10.1146/annurev.ecolsys.38.091206.095543

Yoneshigue-Valentin Y, Loivos AM, Silva RCC, Fernandes DRP (2008) Contribuição ao conhecimento e preservação das algas multicelulares bentônicas do Costão dos Cavaleiros–Macaé, estado do Rio de Janeiro. Iheringia, Série Botânica., 63(1):129-134

Zafar A, Ali I, Rahayu F (2022) Marine seaweeds (biofertilizer) significance in sustainable agricultural activities: A review. IOP Conference Series: Earth and Environmental Science, 974:1-8. https://doi.org/10.1088/1755-1315/974/1/012080