Checklist of marine macroalgae in two contiguous Marine Protected Areas in the south-western Atlantic

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Abstract

Background

The Costa das Algas Environmental Protection Area (EPA) and the Santa Cruz Wildlife Refuge (WR), located in the Espírito Santo Continental Shelf, Brazil, are outstanding marine protected areas due to their high biodiversity, particularly of macroalgae. Together, these two relatively small protected areas (1,150 and 177 km^2, respectively) harbour about a quarter of all macroalgal species recorded in Brazil.

The checklist presented herein updates the algal flora of these two protected areas with data obtained until 2019. Two hundred and sixty-five macroalgal taxa were recorded, most of which with vouchers. Checklists based on the collections of each protected area were published on: "Catálogo de Plantas das Unidades de Conservação do Brasil" (http s://catalogo-ucs-brasil.jbrj.gov.br/).

New information

Besides specimens collected between 2018 and 2019, the algal flora presented herein includes previous records from different Brazilian herbaria (e.g., SP, SPF, ALCB). Herbaria records may include species that do not occur in intertidal reefs (e.g., *Laminaria*). Overall, 249 macroalgal taxa and one marine angiosperm were recorded in the Costa

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das Algas EPA (87 new records) and 136 macroalgal taxa and one marine angiosperm in the Santa Cruz WR (46 new records). All taxa are native to Brazil and nine are endemic to Brazil. Our results provide a taxonomic foundation to support management, long-term monitoring and conservation in these protected areas.

Keywords

algae, south-western Atlantic Ocean, Costa das Algas Environmental Protection Area, Santa Cruz Wildlife Refuge

Introduction

In coastal zones, benthic macroalgae are important primary producers that provide habitat and food for several organisms and multiple benefits for people. They contribute for food, fisheries support, nutrient cycling, coastal protection, water quality and carbon storage (Duffy et al. 2019). However, they are often threatened by several human activities, such as coastal development, urban wastes, invasive species, climate change, oil and gas and industrial activities (Duffy et al. 2019, Hanley et al. 2024).

The Espírito Santo State (ES) encompasses one of Brazil's highest species richness of marine macroalgae, with records of about 400 species (Guimarães 2003, Flora e Funga do Brasil 2023). Its shoreline is composed of beaches, bays, inlets, mangroves, estuaries and lateritic reefs, while its continental shelf harbours a variety of sedimented bottom and rhodolith beds (Bastos et al. 2015, Quaresma et al. 2015), both punctuated by biogenic reefs and other mesoscale benthic features (Holz et al. 2020, Oliveira et al. 2023). The diversity of structurally complex hard bottom habitats contributes to the great intertidal and subtidal diversity of algae (Guimarães 2003, Amado-Filho et al. 2010, Holz et al. 2020). Moreover, the study region is situated in a transitional zone between the tropical and warm temperate phycogeographical provinces (Horta et al. 2001), allowing for the co-occurrence of species with affinities for both warm and cold waters (Horta et al. 2001).

The multiple-use Costa das Algas EPA and the no-take Santa Cruz WR are contiguous and form part of UNESCO's Mata Atlântica Biosphere Reserve. Established in 2010 by Brazil's Federal Government, these marine protected areas (MPAs) aim at the protection of marine biodiversity and management of artisanal fisheries, and were important milestones for the protection of rhodolith beds against large-scale exploitation for the production of agriculture fertilisers [IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis) 2006]. Both areas have great ecological and socioeconomic importance and protect critical habitats that ensure coastal zone protection against erosion and the sustainability of artisanal fisheries, the latter being a major economic activity in the region [ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade) 2023a]. Moreover, they are major tourism destinations, especially during the summer. These areas are faced with several threats, including the contamination by heavy metals from mining wastes transported by the Doce river, with

highly increased concerns after the collapse of the Fundão Dam in November 2015 [ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade) 2023b].

Oliveira-Filho (1977) was the first to highlight the outstanding algal diversity in ES. However, inventories are limited to a few publications (Oliveira-Filho 1969, Oliveira-Filho 1976, Oliveira-Filho 1976, Guimarães 2006, Scherner et al. 2013) and some data was only available in grey literature (Crispino 2000, Barata 2004, Carvalho 2013). Furthermore, most inventories were carried out before 2010 and did not include geographic coordinates or vouchers. In an effort to reduce this knowledge gap, this study aimed at providing an updated checklist of macroalgae for the EPA and the WR.

Project description

Title: This inventory was carried out within the scope of two projects: 1) T1) Aquatic Biodiversity Monitoring Program (PMBA-FEST, RENOVA); 2) Long-Term Ecological Research Program (PELD-Abrolhos/CNPq);

Personnel: The research is Cláudia S Karez Post-Doctoral/CNPq project in the Jardim Botânico do Rio de Janeiro (JBRJ), supervised by Leonardo T Salgado. Identifications were made under the supervision of José Marcos C Nunes (Universidade Federal da Bahia) and Ricardo G Bahia (JBRJ) for crustose coralline algae. Both project are coordinated by Rodrigo L Moura (Universidade Federal do Rio de Janeiro).

Study area description: Sampling was carried out in the Espirito Santo Continental Shelf (ESCS, Oliveira et al. (2020)), south-eastern Brazil, in intertidal reefs within two contiguous marine protected areas, the Costa das Algas EPA (multiple-use) and the Santa Cruz WR (no-take).

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Materials and methods

Study areas

This study focused on macroalgae associated with intertidal reefs in Costa das Algas EPA and Santa Cruz WR, in the Espirito Santo Continental Shelf (ESCS, Oliveira et al. (2020)), south-eastern Brazil. The framework of these reefs, which dwell under a micro-tidal regime and strong fluvial influence, is composed of lateritic rocks interspaced with calcareous formations (Mazzucco et al. 2020). On the Espírito Santo coast,

temperatures range from 25 to 28ºC in the summer and from 22.5 to 24.5ºC in the winter (Instituto Estadual de Meio Ambiente e Recursos Hídricos 2014). Upwelling associated to the intrusion of the South Atlantic Central Water impacts the ESCS, lowering the temperature during short periods between October and March (Guimarães 2003).

Sampling methods

Description: The checklist was primarily based on four field surveys carried out in 2018 and 2019 at eight sites in the intertidal zone (Figs 1, 2), in the two protected areas, covering the four seasons. In addition to field surveys, previous records were obtained from databases: Jabot ("Jardim Botânico do Rio de Janeiro", JBRJ, http://www.jbrj.gov.br/jabot), Reflora ("Herbário Virtual Reflora", https://reflora.jbrj.gov.br/reflora/herbarioVirtual/) and speciesLink ("Centro de Referência em Informação Ambiental", CRIA, https://specieslink.net/search/). Searches were based on the three municipalities "Aracruz", "Fundão" and "Serra" and only records that specified localities within protected areas' perimeters were selected. Species' names were updated following Guiry and Guiry (2023).

Checklists of species with vouchers in the main national herbaria were published on the "Catálogo de Plantas das Unidades de Conservação do Brasil" (https://catalogo-ucs-brasil.jbrj.gov.br/) for both MPAs. Here, we report 30 additional species recorded in our field surveys, but not found in the herbaria. Their abundance was assessed according to the frequencies of occurrence in the eight studied sites and four different seasons in the field surveys (2018-2019), as follows: very common (VC = 28-32 occurrences); common (C = 21-27 occurrences); frequent (F = 3-10 occurrences) and rare (R = 1 or 2 occurrences). Coralline algae were often identified only at the genus level, since species level identification of these algae usually requires molecular analysis.

Quality control: Identifications were based on AlgaeBase (Guiry and Guiry 2023), identification guides, regional and local floristic studies and keys (Oliveira-Filho 1977, Amado-Filho and Yoneshigue-Valentin 1990, Nunes 1998, Nunes 2005, Guimarães 2006 , Figueredo and Tâmega 2007, Pacheco 2011, Bahia 2014, Ximenes et al. 2017, Santos et al. 2020 , Coutinho et al. 2022, Wynne 2022) and validated by taxonomists.

Statistical analysis: Diversity of macroalgae of both MPAs was summarised at family and genus level, as well as endemism and status as native or non-native, based on Flora e Funga do Brasil (2023).

Data resources

Geographic coverage

Description: The Costa das Algas EPA covers 1,150 km^2, with about 96% of its area in the marine environment and the remaining in restingas, beaches and mangroves (Fig. 2).

The Santa Cruz WR covers 177 km^2, 98% in the marine environment. Altogether, these MPAs span about 30 km of shoreline.

Coordinates: Costa das Algas EPA, 20°2'17.42"S, 39°55'2.77"W, in irregular polygon; Santa Cruz WR, 20°0'32.80"S, 40°3'31.49"W, in irregular polygon.

Checklist of marine macroalgae and seagrasses of Costa das Algas EPA and Santa Cruz WR

Phylum Chlorophyta/Ochrophyta/Rhodophyta/Tracheophyta

Notes: Macroalgae recorded in the studied areas are presented in Table 1

Analysis

Taxonomy coverage

Two hundred and sixty-five macroalgal taxa were recorded in the protected areas, including four varieties, one subspecies and one marine angiosperm (Table 1, Suppl. material 1, Suppl. material 2). Costa das Algas EPA (250 taxa) was richer than the Santa Cruz WR (137 taxa) due to the combination of lower sampling effort (only two sampling sites) and smaller area of the latter (Fig. 3).

Records of Rhodophyta consisted of 32 families, 75 genera and 143 species (60% of all taxa) in the Costa das Algas EPA and 29 families, 49 genera and 68 species (53% of all taxa) in the Santa Cruz WR. Chlorophyta consisted of 15 families, 21 genera and 57 species (24% of all taxa) in the Costa das Algas EPA and 10 families, 14 genera and 30 species (22% of all taxa) in the Santa Cruz WR. Ochrophyta was composed of seven families, 16 genera and 39 species (16% of all taxa) in the Costa das Algas EPA and five families, 14 genera and 33 species (24% of all taxa) in the Santa Cruz WR. The most species-rich families were Rhodomelaceae (37 taxa) and Corallinaceae (11 taxa) amongst Rhodophyta; Caulerpaceae (13) and Cladophoraceae (13) amongst Chlorophyta and Dictyotaceae (21) and Sargassaceae (12) amongst Ochrophyta in both MPAs.

Nine species are Brazilian endemic: *Agissea inamoena*, *Alsidium oliveiranum*, *Calliblepharis jolyi*, *Cryptonemia delicatula*, *Hypnea brasiliensis*, *Laurencia longiramea*, *L. translucida* (Rhodophyta); *Laminaria abyssalis* (Ochrophyta) and *Halimeda jolyana* (Chlorophyta) (Nunes 1998, Nunes 2005, Moura et al. 2015, Ximenes et al. 2017, Flora e Funga do Brasil 2023).

One hundred and four species (40% of all taxa), recorded before the 2015 themining disaster, were also presented in our 2018-2019 surveys. There were 86 new occurrences

(34% of all taxa in the MPA) for the Costa das Algas EPA and 45 new ones (33% of all taxa in the MPA) for the Santa Cruz WR in the 2018-2019 surveys. On the other hand, 64 previously recorded taxa (45 Rhodophyta, 14 Chlorophyta and 5 Ochrophyta) were not found in our surveys.

Two hundred species were recorded during the four field surveys and eight sampling sites, however, 71 of which occurred only once or twice during sampling. These species were categorised as rare because they presented a very low frequency of occurrence in both MPAs. Conversely, only eight species (*Codium intertextum, Anadyomene stellata, Dictyosphaeria versluysii, Lobophora variegata, Zonaria tournefortii, Hydrolithon farinosum, Ochtodes secundiramea* and *Dichotomaria marginata*) were conspicuous and were found at all eight sampling sites in all seasons.

Discussion

Rhodophyta comprised 70% of the species recorded in previous inventory in the Espirito Santo State, which were carried out between 1969 and 2004, while Chlorophyta and Ochrophyta, class Phaeophyceae, comprised 15% (Guimarães 2003). Proportions recorded herein, from surveys carried out between 2018 and 2019, are slightly different once about 60% of the species recorded in this latter surveys belong to Rhodophyta. While Rhodophyta encompasses a high proportion of small filamentous and delicate species and tends to present higher richeness in areas with better environmental quality, Chlorophyta are smaller and filamentous forms, that tends to be more tolerant to changes in the environment [WFD-UKTAG (Water Framework Directive - United Kingdom Technical Advisory Group) 2009]. The red algal order, Ceramiales, which tends to thrive under better environmental quality (Bermejo et al. 2012) encompassed the higher richness in the study area (66 species), both before and after the 2015 mining disaster, but 22 of the previously recorded species of this group were not found during the latter surveys. An inventory carried out in the 2000s (Guimarães 2003), compared the Ceramiales flora of Espírito Santo (115 species) with surveys carried ou 30 years earlier (Oliveira-Filho 1969) and recorded no differences in the algal composition. Ecological impacts of terrestrial nutrients, sediments and pollutants are likely to be species-specific (Díaz-Pulido et al. 2007), and may lead to insidious changes in the macroalgal assemblages. The two protected areas studied herein are historically degraded due to multiple chronic impacts (Costa et al. 2021, Scherner et al. 2013), but the contaminants from the 2015 mining disaster are especially concerning and deserve further monitoring efforts (Quaresma et al. 2021, Coppo et al. 2023).

New records of algae after the mining disaster are due either to the increased sampling effort near the Doce river mouth or to taxonomic studies during the two last decades. Some of these newly recorded taxa are indeed recent description, and it should be also mentioned that amongst the 100 new records comprise rare species. Furthermore, there are new records amongst Dictyotales, Fucales and Corallinales, which are the most abundant algal groups and have an intricate taxonomy due to morphological variability associated to environmental conditions (Bahia 2014, González-Nieto et al. 2020). For

example, in a recent molecular study, 10 species of *Sargassum* (*S. bermudense*, *S. buxifolium*, *S. cymosum*, *S. filipendula*, *S. fluitans*, *S. furcatum*, *S. hystrix*, *S. natans*, *S. polyceratium* and *S. vulgare*) were synonymised under *S. cymosum* (González-Nieto et al. 2020). Here, we did not use González-Nieto et al. (2020) taxonomic arrangement, as their analyses were largely based on data from the Caribbean with only one sequence from Brazil.

Our new algal records do not mean environmental quality improvements in the Espirito Santo coast. Indeed, new algal records are frequent in degraded environments, which tend to receive adequate monitoring efforts after enviroments impacts. Examples include Santos (Oliveira and Qi 2003), Sepetiba (Amado-Filho et al. 2003) and Guanabara bays (De Paula et al. 2020), as well as the vicinity of other urban centres (Scherner et al. 2013). Therefore, actual decreases in diversity are frequent despite larger checklists. For instance, Amado-Filho et al. (2003) recorded reduction of Rhodophyta richness, together with dominance of *Sargassum* spp. and *Padina gymnospora* under high metal concentrations in Sepetiba Bay (Brazil). Algal assemblages are excellent indicators of climate and anthropogenic impacts (Mazzucco et al. 2020), Carneiro et al. 2023).

The Costa das Algas Environment Protection Area (EPA) and Santa Cruz Wildlife Refuge (WR) are marine biodiversity hotspots threatened by mining wastes from the 2015 disaster, as well as by uncontrolled tourism, shrimp trawling, irregular discharge of chemicals, oils and solid wastes., invasive species and climate changes [ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade) 2023b]. Long-term monitoring of these highly relevant and threatened MPAs is essential to guide management actions and restoration efforts, and the baseline data herein providesa relevant foundation for further assessments.

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Author contributions

Conceptualisation: Claudia S. Karez, José MC Nunes, Ricardo G Bahia, Leonardo T Salgado, Rodrigo L Moura. Field collection of macroalgae: Ricardo G Bahia, Pedro

Cardial, Gabriella A Leal, Manoela B Lyra. Specimens identification: Ricardo G Bahia, José MC Nunes, Gabriel N Santos, Pedro Cardial, Gabriella A Leal, Manoela B Lyra. Data organisation and curation: Clarice CM Ribeiro, José MC Nunes, Gabriel N Santos, Ricardo G Bahia, Carolina C Silva, List validation: Gabriel N Santos and Ricardo G Bahia. Manuscript writing: Claudia S Karez, Ricardo G Bahia, José MC Nunes, Gabriel N Santos, Rodrigo L Moura, Paulo S Salomon, Leonardo T Salgado. Supervision: Leonardo T Salgado, Rodrigo L Moura.

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Figure 1.

Shallow reef benthic assemblages adjacent to the coastline dominated by algae in the Costa das Algas EPA and Santa Cruz WR (2018-2019). **A** Zoanthid (*Palythoa* sp.) and algae; **B** *Halimeda* sp.; **C** *Vidalia obtusilosa*; **D** *Tricleocarpa cylindrica;* **E** Maerls formed by living mono-specific CCA covering the sea bed associated with *Dictyoperis delicatula*; **F** Living rhodoliths surrounded by nodules covered by turf; **G** Living rhodoliths associated with *Padina* sp. and *Sargassum* sp.; **H** Collection of macroalgae in the field; Photos: (A-C) A. Bertoncini; Photos (D-H) F. Moraes.

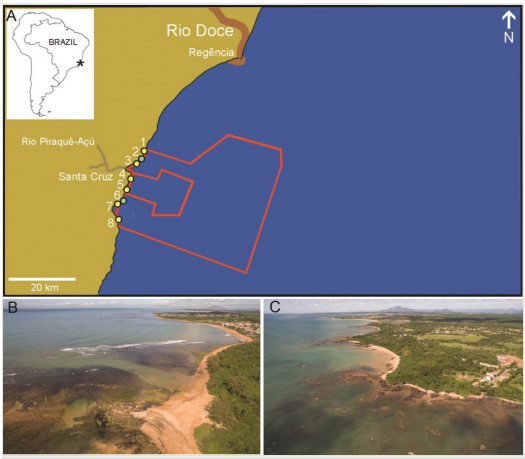

Figure 2.

Site location and views of the two studied MPAs. **A** Sampling sites in the multiple use Costa das Algas Environmental Protection Area (larger polygon) and in the no-take Santa Cruz Wildlife Reserve (smaller polygon); **B** Costa das Algas EPA; **C** Santa Cruz WR. Photos: F. Moraes.

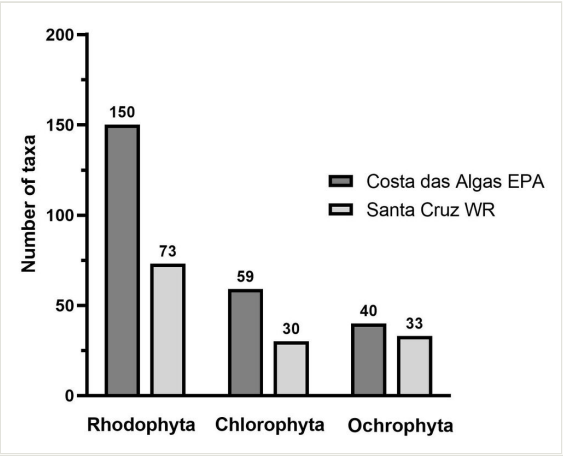

Figure 3.

Number of macroalgal taxa of Rhodophyta, Chlorophyta and Ochrophyta in the Costa das Algas EPA and the Santa Cruz WR (ES).

Table 1.

List of macroalgae of the Costa das Algas EPA (CA) and the Santa Cruz WR (SC) recorded in the present study (2018-2019 survey) and previous period (1969-2004). R = Record (R = taxa present in both periods: before 2004 and in this study (2018-2019); 1st R = first record to MPAs in this study (2018-2019); PR = taxa present only before 2004); A = Abundance (Ra = Rare; F = Frequent; C = Common; VC = Very common; Blank = unknown).

PHYLUM/CLASS/ORDER/FAMILY/SPECIES	Costa das Algas EPA	Santa Cruz WR	Period record	Abundance
CHLOROPHYTA				
CLASS ULVOPHYCEAE				
BRYOPSIDALES				
Bryopsidaceae				
Bryopsis pennata J.V.Lamouroux 1809	X	X	PR	
Bryopsis plumosa (Hudson) C.Agardh 1823	X		PR	
Caulerpaceae				
Caulerpa ambigua Okamura 1897	X		1st R	Ra
Caulerpa chemnitzia (Esper) J.V.Lamouroux 1809	X	X	R	F
Caulerpa cupressoides (Vahl) C.Agardh 1817	X	X	R	F
Caulerpa cupressoides var. *lycopodium* Weber Bosse 1898	X		R	F
Caulerpa cupressoides var. *mamillosa* (Montagne) Weber Bosse 1898	X		PR	F
Caulerpa fastigiata Montagne 1837	X		R	F
Caulerpa lanuginosa J.Agardh 1873	X	X	R	F
Caulerpa mexicana Sonder ex Kützing 1849	X	X	R	F
Caulerpa prolifera (Forsskål) J.V.Lamouroux 1809	X	X	R	F
Caulerpa racemosa (Forsskål) J.Agardh 1873	X	X	R	C
Caulerpa sertularioides (S.G.Gmelin) M.Howe 1905	X	X	R	F
Caulerpa verticillata J.Agardh 1847	X		1st R	F
Caulerpa webbiana Montagne 1837	X		1st R	Ra
Codiaceae				
Codium decorticatum (Woodward) M.A.Howe 1911	X		R	
Codium intertextum Collins & Hervey 1917	X	X	R	VC
Codium isthmocladum Vickers 1905	X	X	R	C

Codium spongiosum Harvey 1855	X		PR	
Codium taylorii P.C.Silva 1960	X	X	R	F
Derbesiaceae				
Derbesia marina (Lyngbye) Solier 1846	X		1st R	Ra
Dichotomosiphonaceae				
Avrainvillea longicaulis (Kützing) G.Murray & Boodle 1889	X		PR	
Avrainvillea nigricans Decaisne 1842	X		1st R	Ra
Halimedaceae				
Halimeda discoidea Decaisne 1842	X		1st R	Ra
Halimeda jolyana Ximenes, Bandeira-Pedrosa, Cassano, Oliveira-Carvalho, Verbruggen & S.M.B.Pereira 2017	X	X	R	C
Penicillus capitatus Lamarck 1813	X		1st R	Ra
CLADOPHORALES				
Anadyomenaceae				
Anadyomene stellata (Wulfen) C.Agardh 1823	X	X	R	VC
Anadyomene rhizoidifera A.B.Joly & S.Pereira 1973	X		R	
Microdictyon boergesenii Setchell 1925		X	R	
Boodleaceae				
Boodlea struveoides M.Howe 1918	X	X	1st R	Ra
Cladophoropsis membranacea Børgesen 1905	X	X	R	F
Phyllodictyon anastomosans (Harvey) Kraft & M.J.Wynne 1996	X		1st R	
Cladophoraceae				
Chaetomorpha aerea (Dillwyn) Kützing 1849	X	X	R	
Chaetomorpha antennina (Bory) Kützing 1847	X		1st R	Ra
Chaetomorpha brachygona Harvey 1858	X		1st R	Ra
Chaetomorpha linum (O.F.Müller) Kützing 1843	X		1st R	
Chaetomorpha minima Collins & Hervey 1917	X		1st R	Ra
Chaetomorpha nodosa Kützing 1849	X		PR	
Cladophora coelothrix Kützing 1843	X		R	Ra
Cladophora corallicola Børgesen 1913	X	X	PR	
Cladophora laetevirens (Dillwyn) Kützing 1843	X	X	1st R	F

Cladophora prolifera (Roth) Kützing 1843	X	X	R	F
Cladophora rupestris (Linnaeus) Kützing 1843	X		PR	
Cladophora vagabunda (Linnaeus) Hoek 1963	X	X	R	Ra
Willeella ordinata Børgesen 1930	X	X	R	Ra
Siphonocladaceae F.Schmitz				
Dictyosphaeria cavernosa (Forsskål) Børgesen 1932	X	X	R	
Dictyosphaeria versluysii Weber Bosse 1905	X	X	R	VC
Siphonocladus tropicus (P.Crouan & H.Crouan) J.Agardh 1887	X		PR	
Valoniaceae				
Valonia aegagropila C.Agardh 1823	X	X	R	F
Valonia macrophysa Kützing 1843	X	X	R	F
Valonia utricularis (Roth) C.Agardh 1823	X		PR	
DASYCLADALES				
Polyphysaceae				
Parvocaulis myriosporus C.W.Nascimento Moura & J.C.DeAndrade 2014	X		1st R	Ra
ULOTRICHALES				
Gayraliaceae				
Gayralia oxysperma (Kützing) K.L.Vinogradova ex Scagel & al. 1989	X		PR	
ULVALES				
Ulvaceae				
Ulva clathrata (Roth) C.Agardh 1811	X		PR	
Ulva flexuosa Wulfen 1803	X	X	R	F
Ulva lactuca Linnaeus 1753	X	X	R	Ra
Ulva linza Linnaeus 1753	X	X	R	
Ulva rigida C.Agardh 1823	X	X	R	F
Ulvellaceae				
Ulvella scutata R.Nielsen, C.J.O'Kelly & B.Wysor 2013	X		PR	
Ulvella viridis (Reinke) R.Nielsen, C.J.O'Kelly & B.Wysor 2013	X		PR	
Total	59	30		

OCHROPHYTA				
CLASS PHAEOPHYCEAE				
DICTYOTALES				
Dictyotaceae				
Canistrocarpus cervicornis (Kützing) De Paula & De Clerck 2006	X	X	R	C
Canistrocarpus crispatus (J.V.Lamouroux) De Paula & De Clerck 2006	X	X	1st R	Ra
Dictyopteris delicatula J.V.Lamouroux 1809	X	X	R	F
Dictyopteris plagiogramma (Montagne) Möbius 1889	X	X	R	F
Dictyopteris polypodioides (De Candolle) J.V.Lamouroux 1809	X	X	R	F
Dictyota caribaea Hörnig & Schnetter 1992	X		1st R	Ra
Dictyota ciliolata Sonder ex Kützing 1859	X	X	R	F
Dictyota crenulata J.Agardh 1847	X	X	1st R	F
Dictyota dichotoma (Hudson) J.V.Lamouroux 1809	X		PR	
Dictyota jamaicensis W.R.Taylor 1960	X	X	R	F
Dictyota menstrualis Schnetter, Hörning & Weber-Peukert 1987	X	X	R	F
Dictyota mertensii (C.Martius) Kützing 1859	X	X	R	F
Lobophora variegata (J.V.Lamouroux) Womersley ex E.C.Oliveira 1977	X	X	R	VC
Padina antillarum (Kützing) Piccone 1886	X	X	R	F
Padina boergesenii Allender & Kraft 1983		X	1st R	F
Padina gymnospora (Kützing) Sonder 1871	X	X	R	F
Padina sanctae-crucis Børgesen 1914	X		1st R	F
Spatoglossum schroederi (C.Agardh) Kützing 1859	X	X	R	C
Stypopodium zonale (J.V.Lamouroux) Papenfuss 1940	X	X	PR	
Zonaria tournefortii (J.V.Lamouroux) Montagne 1846	X	X	R	VC
Zonaria zonata C.Agardh	X	X	1st R	Ra
ECTOCARPALES				
Acinetosporaceae				
Acinetospora filamentosa (Noda) Yaegashi, Uwai & Kogame 2015		X	1st R	Ra

Feldmannia irregularis (Kützing) Hamel 1939	X	X	1st R	Ra
Feldmannia mitchelliae (Harvey) H.-S.Kim 2010		X	1st R	Ra
Scytosiphonaceae				
Chnoospora minima (Hering) Papenfuss 1956	X		1st R	Ra
Colpomenia sinuosa (Mertens ex Roth) Derbès & Solier 1851	X	X	R	C
Hydroclathrus clathratus (C.Agardh) M.Howe 1920	X	X	R	F
FUCALES				
Sargassaceae				
Sargassum cymosum C.Agardh 1820	X		1st R	Ra
Sargassum cymosum var. *nanum* E.de Paula & E.C.Oliveira	X		1st R	
Sargassum filipendula C.Agardh 1824	X	X	R	F
Sargassum furcatum Kützing 1843	X	X	R	Ra
Sargassum hystrix J.Agardh 1847	X	X	R	F
Sargassum novae-hollandiae P.C.Silva 1996	X	X	1st R	F
Sargassum platycarpum Montagne 1842	X		PR	
Sargassum polyceratium Montagne 1837	X	X	1st R	F
Sargassum ramifolium Montagne 1843	X	X	R	F
Sargassum rigidulum Kützing 1849	X	X	1st R	F
Sargassum stenophyllum C.Martius 1828	X	X	R	F
Sargassum vulgare C.Agardh 1820	X	X	1st R	F
LAMINARIALES				
Laminariaceae				
Laminaria abyssalis A.B.Joly & E.C.Oliveira 1967	X		PR	
SCYTOTHAMNALES				
Bachelotiaceae				
Bachelotia antillarum (Grunow) Gerloff 1959	X		1st R	Ra
SPHACELARIALES				
Sphacelariaceae				
Sphacelaria brachygonia Montagne 1843	X		PR	
Sphacelaria rigidula Kützing 1843	X	X	R	F
Total	40	33		

RHODOPHYTA				
CLASS FLORIDEOPHYCEAE				
CERAMIALES				
Callithamniaceae				
Aglaothamnion felipponei (Howe) Aponte, Ballantine & J.N.Norris 1994	X		PR	
Aglaothamnion herveyi (M.Howe) N.E.Aponte, D.L.Ballantine, & J.N.Norris 1994	X		1st R	Ra
Spyridia aculeata (C.Agardh ex Decaisne) Kützing 1843	X		PR	
Spyridia clavata Kützing 1841		X	1st R	Ra
Spyridia filamentosa (Wulfen) Harvey 1833	X		1st R	Ra
Spyridia hypnoides (Bory) Papenfuss 1968	X		PR	
Ceramiaceae				
Centroceras gasparrinii (Meneghini) Kützing 1849	X	X	1st R	F
Ceramium luetzelburgii O.C.Schmidt 1924	X	X	1st R	Ra
Ceramothamnion brasiliensis (A.B.Joly) M.J.Wynne & C.W.Schneider 2023	X		PR	
Ceramothamnion codii H.Richards 1901		X	1st R	Ra
Gayliella dawsonii (A.B.Joly) Barros-Barreto & F.P.Gomes 2020	X		1st R	F
Pseudoceramium caraibicum (H.E.Petersen & Børgesen) Barros-Barreto, Maggs & M.A.Jaramillo 2023	X		1st R	Ra
Delesseriaceae				
Acrosorium ciliolatum (Harvey) Kylin 1924	X		1st R	Ra
Caloglossa leprieurii (Montagne) G.Martens1869	X		PR	
Cryptopleura crispa Kylin 1924	X		PR	
Cryptopleura ramosa (Hudson) L.Newton 1931	X		1st R	Ra
Dasya corymbifera J.Agardh 1841	X		R	Ra
Dasya rigidula (Kützing) Ardissone 1878	X		1st R	Ra
Dictyurus occidentalis J.Agardh 1847	X		1st R	Ra
Heterosiphonia crispella (C.Agardh) M.J.Wynne 1985	X	X	R	Ra
Heterosiphonia gibbesii (Harvey) Falkenberg 1901	X	X	R	F
Taenioma perpusillum (J.Agardh) J.Agardh 1863	X		1st R	Ra

Thuretia bornetii Vickers 1905		X	1st R	Ra
Rhodomelaceae				
Acanthophora spicifera (M.Vahl) Børgesen 1910	X	X	R	F
Alsidium oliveiranum S.M.Guimarães & M.T.Fujii 2019	X		PR	
Alsidium seaforthii (Turner) J.Agardh 1841	X	X	R	C
Bostrychia binderi Harvey 1849	X	X	1st R	F
Bostrychia montagnei Harvey 1853	X		PR	
Bostrychia radicans (Montagne) Montagne 1842	X		PR	
Bostrychia scorpioides (Hudson) Montagne 1842	X		PR	
Bostrychia tenella (J.V.Lamouroux) J.Agardh 1863	X		R	Ra
Bryocladia cuspidata (J.Agardh) De Toni 1903	X	X	R	
Carradoriella denudata (Dillwyn) Savoie & G.W.Saunders 2019	X	X	1st R	Ra
Chondria capillaris (Hudson) M.J.Wynne 1991	X		PR	
Chondria littoralis Harvey 1853	X		PR	
Chondria sedifolia Harvey 1853	X		PR	
Dipterosiphonia dendritica (C.Agardh) F.Schmitz 1897	X	X	1st R	Ra
Herposiphonia nuda Hollenberg 1968	X	X	1st R	Ra
Herposiphonia secunda (C.Agardh) Ambronn 1880	X	X	R	
Herposiphonia tenella (C.Agardh) Ambronn 1880	X		R	Ra
Laurencia aldingensis Y.Saito & Womersley 1974	X		PR	
Laurencia arbuscula Sonder 1845	X		1st R	F
Laurencia dendroidea J.Agardh 1852	X	X	R	F
Laurencia catarinensis Cordeiro-Marino & Fujii 1985	X		PR	
Laurencia intricata J.V.Lamouroux 1813		X	1st R	
Laurencia filiformis (C.Agardh) Montagne 1845	X		PR	
Laurencia longiramea Cassano, G.N.Santos, J.M.C.Nunes, M.C.Oliveira & M.T.Fujii 2019	X		PR	
Laurencia oliveirana Yoneshigue-Valetin, M.J.Wynne & Cassano 2022	X		R	Ra
Laurencia translucida Fujii & Cordeiro-Marino 1996	X		PR	
Laurencia venusta Yamada 1931	X		PR	

Melanothamnus ferulaceus (Suhr ex J.Agardh) Díaz-Tapia & Maggs 2017	X		1st R	F
Melanothamnus gorgoniae (Harvey) Díaz-Tapia & Maggs 2017		X	1st R	Ra
Melanothamnus tongatensis (Harvey ex Kützing) Díaz-Tapia & Maggs 2017		X	R	Ra
Osmundaria obtusiloba (C.Agardh) R.E.Norris 1991	X	X	R	C
Palisada corallopsis (Montagne) Sentíes, Fujii & Díaz-Larrea 2008	X		1st R	Ra
Palisada flagellifera (J.Agardh) K.W.Nam 2007	X		PR	
Palisada furcata (Cordeiro-Marino & M.T.Fujii) Cassano & M.T.Fujii 2012	X	X	R	F
Palisada perforata (Bory) K.W.Nam 2007	X	X	R	F
Polysiphonia sertularioides (Grateloup) J.Agardh 1863	X	X	1st R	F
Polysiphonia subtilissima Montagne 1840		X	R	Ra
Wrangeliaceae				
Anotrichium elongatum (Harvey) Baldock 1976	X	X	PR	
Griffithsia globulifera Harvey ex Kützing 1862		X	1st R	Ra
Griffithsia schousboei Montagne 1841	X	X	1st R	F
Haloplegma duperreyi Montagne 1842	X		1st R	
Wrangelia argus (Montagne) Montagne 1856	X		R	F
Wrangelia penicillata (C.Agardh) C.Agardh 1828	X		PR	
CORALLINALES				
Corallinaceae				
Arthrocardia flabellata (Kützing) Manza 1940	X		PR	
Arthrocardia variabilis (Harvey) Weber Bosse 1904	X		1st R	
Corallina officinalis Linnaeus 1758	X		R	F
Corallina panizzoi R.Schnetter & U.Richter 1979	X	X	R	F
Jania capillacea Harvey 1853	X		PR	
Jania crassa J.V.Lamouroux 1821	X		PR	
Jania cubensis Montagne ex Kützing 1849	X	X	1st R	F
Jania pedunculata var. *adhaerens* (J.V.Lamouroux) A.S.Harvey, Woelkerling & Reviers 2020	X		1st R	F

Jania rubens (Linnaeus) J.V.Lamouroux 1816	X		R	Ra
Jania sagittata (J.V.Lamouroux) Blainville 1834	X		PR	
Jania subulata (Ellis & Solander) Sonder 1848	X		R	Ra
Hydrolithaceae				
Hydrolithon farinosum (J.V.Lamouroux) Penrose & Y.M.Chamberlain 1993	X	X	1st R	VC
Hydrolithon sp. (Foslie) Foslie, 1909	X	X	PR	
Lithophyllaceae				
Amphiroa anastomosans Weber Bosse 1904	X	X	R	C
Amphiroa beauvoisii J.V.Lamouroux 1816	X		PR	
Amphiroa brasiliana Decaisne 1842	X		1st R	Ra
Amphiroa fragilissima (Linnaeus) J.V.Lamouroux 1816	X	X	R	F
Amphiroa rigida J.V.Lamouroux 1816	X	X	R	F
Lithophyllum corallinae (P.Crouan & H.Crouan) Heydrich 1897		X	1st R	F
Lithophyllum prototypum (Foslie) Foslie 1905	X		1st R	F
Lithophyllum sp. Philippi, 1837	X	X	1st R	F
Porolithaceae				
Harveylithon roseum C.Liu & S.-M.Lin 2018	X	X	1st R	F
Spongitidaceae				
Neogoniolithon brassica-florida (Harvey) Setchell & L.R.Mason 1843	X		1st R	F
GELIDIALES				
Gelidiaceae				
Gelidium americanum (W.R.Taylor) Santelices 1976	X		PR	
Gelidium capense (S.G.Gmelin) P.C.Silva 1987	X	X	R	F
Gelidium floridanum W.R.Taylor 1943	X	X	R	F
Gelidium pusillum (Stackhouse) Le Jolis 1863	X		PR	
Gelidium torulosum Kützing 1868	X		PR	
Gelidiellaceae				
Gelidiella acerosa (Forsskål) Feldmann & Hamel 1934	X	X	R	C
Gelidiella ligulata E.Y.Dawson 1953	X		1st R	Ra
Parviphycus trinitatensis (W.R.Taylor) M.J.Wynne 2010	X		1st R	Ra

Pterocladiaceae				
Pterocladiella bartlettii (W.R.Taylor) Santelices 1998	X	X	R	F
Pterocladiella beachiae Freshwater 2001	X	X	1st R	F
Pterocladiella capillacea (S.G.Gmelin) Santelices & Hommersand 1997	X		R	Ra
GIGARTINALES				
Caulacanthaceae				
Catenella caespitosa (Withering) L.M.Irvine 1976	X	X	R	F
Cystocloniaceae				
Calliblepharis jolyi E.C.Oliveira 1970	X		PR	
Hypnea brasiliensis P.B.Jesus, Nauer & J.M.C.Nunes 2016	X	X	1st R	F
Hypnea cervicornis J.Agardh 1851	X	X	R	F
Hypnea pseudomusciformis Nauer, Cassano & M.C.Oliveira 2015	X	X	R	C
Gigartinaceae				
Chondracanthus acicularis (Roth) Fredericq 1993	X	X	R	F
Chondracanthus teedei (Mertens ex Roth) Kützing 1843	X		PR	
Phyllophoraceae				
Gymnogongrus griffithsiae (Turner) C.Martius 1833	X		R	Ra
Petroglossum undulatum C.W.Schneider 1976	X	X	R	Ra
Rhizophyllidaceae				
Ochtodes secundiramea (Montagne) M.Howe 1920	X	X	1st R	VC
Solieriaceae				
Meristotheca gelidium (J.Agardh) E.J.Faye & M.Masuda 2004	X		R	Ra
Solieria filiformis (Kützing) Gabrielson 1985	X	X	R	F
GRACILARIALES				
Gracilariaceae				
Gracilaria caudata J.Agardh 1852	X		PR	
Gracilaria cearensis (A.B.Joly & Pinheiro) A.B.Joly & Pinheiro 1966	X	X	1st R	Ra
Gracilaria cervicornis (Turner) J.Agardh 1852	X	X	R	F
Gracilaria cuneata Areschoug 1854	X	X	R	Ra

Gracilaria domingensis (Kützing) Sonder ex Dickie 1874	X	X	1st R	F
Gracilaria ferox J.Agardh 1852	X		1st R	
Gracilaria flabelliformis (P.Crouan & H.Crouan) Fredericq & Gurgel 2004	X		1st R	
Gracilaria flabelliformis subsp. *simplex* Gurgel, Fredericq & J.N.Norris 2004	X		1st R	Ra
Gracilaria foliifera (Forsskål) Børgesen 1932	X		1st R	
Gracilaria mammillaris (Montagne) M.Howe 1918	X		PR	
Gracilaria rangiferina (Kützing) Piccone 1886	X		1st R	Ra
HALYMELIALES				
Grateloupiaceae				
Grateloupia filicina (J.V.Lamouroux) C.Agardh 1822	X	X	R	Ra
Grateloupia filiformis Kützing 1849	X		PR	
Halymeniaceae				
Cryptonemia bermudensis Collins & M.Howe) C.W.Schneider, C.E.Lane & G.W.Saunders 2018	X		PR	
Cryptonemia bengryi W.R.Taylor 1960	X		PR	
Cryptonemia delicatula Joly & Cordeiro 1966	X		PR	
Cryptonemia seminervis (C.Agardh) J.Agardh 1846	X	X	R	F
Halymenia brasiliana S.M.P.B.Guimarães & M.T.Fujii 1998	X		1st R	Ra
Halymenia elongata C.Agardh 1822	X		PR	
Halymenia floridana J.Agardh 1892	X		1st R	Ra
HAPALIDIALES				
Hapalidiaceae				
Lithothamnion muelleri Lenormand ex Rosanoff 1866	X		PR	
Phymatolithon sp. Foslie, 1898, nom. cons.	X		1st R	F
Roseolithon crispatum (Hauck) P.W.Gabrielson, Maneveldt, Hughey & V.Peña 2023	X	X	R	C
Roseolithon sp. L.M.Coutinho & Barros-Barreto, 2021	X	X	1st R	
Mesophyllumaceae				
Mesophyllum sp. Me.Lemoine, 1928	X		1st R	F
NEMALIALES				
Galaxauraceae				

Dichotomaria marginata (J.Ellis & Solander) Lamarck 1816	X	X	R	VC
Dichotomaria obtusata (J.Ellis & Solander) Lamarck 1816	X	X	R	F
Galaxaura rugosa (J.Ellis & Solander) J.V.Lamouroux 1816	X	X	1st R	Ra
Tricleocarpa cylindrica (J.Ellis & Solander) Huisman & Borowitzka 1990	X	X	R	F
Tricleocarpa fragilis (Linnaeus) Huisman & R.A.Townsend 1993	X	X	1st R	C
Liagoraceae				
Gloiocallis dendroidea (P.Crouan & H.Crouan) Showe M.Lin, Huisman & D.L.Ballantine 2014	X		1st R	Ra
Helminthocladia calvadosii (J.V.Lamouroux ex Duby) 1915	X		PR	
Liagora ceranoides J.V.Lamouroux 1816	X		1st R	Ra
Scinaiaceae				
Scinaia halliae (Setchell) Huisman 1985	X		R	F
PEYSSONNELIALES				
Peyssonneliaceae				
Agissea inamoena (Pilger) Pestana, Lyra, Cassano & J.M.C. Nunes 2021	X		PR	
Peyssonnelia armorica (P.Crouan & H.Crouan) Weber Bosse 1916	X		PR	
Peyssonnelia boergesenii (S.G.Gmelin) Decaisne ex J.Agardh 1916	X		PR	
Peyssonnelia sp. Decaisne, 1841	X	X	R	C
PLOCAMIALES				
Plocamiaceae				
Plocamium brasiliense (Greville) M.Howe & W.R.Taylor 1931	X	X	R	F
RHODYMENIALES				
Champiaceae				
Champia feldmannii Díaz-Piferrer 1977	X	X	R	F
Champia vieillardii Kützing 1866	X	X	1st R	F
Lomentariaceae				
Ceratodictyon planicaule (W.R.Taylor) M.J.Wynne 2011	X	X	1st R	Ra
Ceratodictyon variabile (J.Agardh) R.E.Norris 1987	X	X	1st R	F

Rhodymeniaceae				
Botryocladia occidentalis (Børgesen) Kylin 1931	X	X	R	Ra
Botryocladia wynnei D.L.Ballantinne 1985	X	X	1st R	F
Rhodymenia divaricata E.Y.Dawson 1941	X		R	
Rhodymenia pseudopalmata (J.V.Lamouroux) P.C.Silva 1952	X	X	R	F
SPOROLITHALES				
Sporolithaceae				
Sporolithon episporum (M.Howe) E.Y.Dawson 1960	X		1st R	F
Sporolithon sp. Heydrich, 1897		X	1st R	F
Total	150	73		
TOTAL	249	136		
TRACHEOPHYTA				
CLASS MONOCOTS				
ALISMATALES				
Cymodoceaceae				
Halodule wrightii Ascherson 1868	X	X	1st R	

Supplementary materials

Suppl. material 1: Checklist of

Authors: Authors: Claudia S. Karez, Ricardo G. Bahia, José M.C. Nunes, Gabriel N. Santos, Rodrigo L. Moura, Paulo S. Salomon, Clarice C. M. Ribeiro, Carolina S. Silva, Pedro Cardial, Gabriella A. Leal, Manoela B. Lyra, Leonardo T. Salgado
Data type: Excel - taxonomy
Brief description: Checklist of marine macroalgae of the Costa das Algas Environmental Protected Area.
Download file (51.54 kb)

Suppl. material 2: Checklist of

Authors: Authors: Claudia S. Karez, Ricardo G. Bahia, José M.C. Nunes, Gabriel N. Santos, Rodrigo L. Moura, Paulo S. Salomon, Clarice C. M. Ribeiro, Carolina S. Silva, Pedro Cardial, Gabriella A. Leal, Manoela B. Lyra, Leonardo T. Salgado
Data type: Excel - Taxonomy
Brief description: Checklist of marine macroalgae of the Santa Cruz Wildlife Refuge.
Download file (39.50 kb)