

SHORT COMMUNICATION

Checklist of benthic algae from beaches and rocky outcrops on the northeast coast of Pará state, Brazilian Amazonia

Alexandre de Gusmão PEDRINI¹, Gabriel Irene Pereira GUARINO¹, Felipe dos Santos Pereira DINIZ¹, José Eduardo MARTINELLI FILHO^{2*} 

¹ Universidade do Estado do Rio de Janeiro, Instituto de Biologia Roberto Alcântara Gomes, Departamento de Biologia Vegetal, Rua São Francisco Xavier, 524, Pavilhão Haroldo Lisboa da Cunha, CEP 20550-013, Rio de Janeiro, RJ, Brazil

² Universidade Federal do Pará, Instituto de Geociências, Laboratório de Oceanografia Biológica, Avenida Augusto Corrêa, 1, CEP 66075-110, Belém, Pará, Brazil

* Corresponding author: martinelli@ufpa.br;  <https://orcid.org/0000-0001-8445-1332>

ABSTRACT

We present a checklist with 23 taxa of the benthic phycological flora on three beaches on the northeast coast of Pará state, in the Brazilian Amazon, a rarely surveyed area for algae. Collections were made on substrates like rocky outcrops at Salinópolis municipality, and on trunks, branches and pneumatophores of *Laguncularia racemosa* and artificial substrates at Marapanim municipality. Despite the limited geographic scale of the sampling, we provide ten new citations for the benthic, marine and estuarine algal taxa of the Pará state coast: six Chlorophyta (*Bryopsis pennata*, *Cladophora coelothrix*, *C. conferta*, *Gayralia brasiliensis*, *Pseudorhizoclonium africanum* and *Ulva chaetomorphoides*), two Rhodophyta (*Caloglossa confusa*, *Centroceras gasparrinii*), one Ochrophyta (*Bachelotia antillarum*) and one Cyanophyta (*Coleofasciculus chthonoplastes*).

KEYWORDS: Amazon shelf, Neotropical region, phycology, South America, coastal algae

Inventário de algas bentônicas de praias e matacões rochosos da costa nordeste do Pará, Amazônia brasileira

RESUMO

Apresentamos um inventário com 23 táxons da flora ficológica bentônica em praias da costa nordeste do estado do Pará, na Amazônia brasileira, uma região raramente amostrada para algas. As coletas foram realizadas em substratos como matacões no município de Salinópolis, e em troncos, galhos e pneumatóforos de *Laguncularia racemosa* e substratos artificiais no município de Marapanim. Apesar das limitações da amostragem, nós registramos dez novas citações de algas marinhas e estuarinas bentônicas para a costa do estado do Pará: seis Chlorophyta (*Bryopsis pennata*, *Cladophora coelothrix*, *C. conferta*, *Gayralia brasiliensis*, *Pseudorhizoclonium africanum* e *Ulva chaetomorphoides*), duas Rhodophyta (*Caloglossa confusa* e *Centroceras gasparrinii*), uma Ochrophyta (*Bachelotia antillarum*) e uma Cyanophyta (*Coleofasciculus chthonoplastes*).

PALAVRAS-CHAVE: Plataforma amazônica, região neotropical, ficologia, América do Sul, algas costeiras

The Amazon coast and shelf is a unique region, leading to the establishment of a singular ecological province, the North Brazil shelf (Spalding *et al.* 2007). The region includes the coast of Pará state (Brazil), which is dominated by extensive mangroves, vegetated dune-beach ridges and channels, and displays a rich flora, which lacks systematic and detailed studies (Forzza *et al.* 2010). The polyphyletic algae are one of these taxa of limited knowledge, with only seven published studies for the coast of Amapá and Pará states (Paula *et al.* 1989;

Fernandes *et al.* 2005; Fernandes and Alves 2011; Széchy *et al.* 2012; Moura *et al.* 2016; Sissini *et al.* 2017; Vale *et al.* 2018).

A low diversity of macroalgae is known for the Brazilian Amazon coast, when compared to southern Brazil (Oliveira Filho 1977). The algal diversity is probably underestimated for the region, since recent articles related to macroalgae on the Amazon coast were published (Széchy *et al.* 2012; Sissini *et al.* 2017), with highlights to the existence of a benthic flora at mesophotic reefs, composed of 25 Rhodophyta, six Chlorophyta and four Ochrophyta taxa (Moura *et al.* 2016).

CITE AS: Pedrini, A.G.; Guarino, G.I.P.; Diniz, F.S.P.; Martinelli Filho, J.E. 2021. Checklist of benthic algae from beaches and rocky outcrops on the northeast coast of Pará state, Brazilian Amazonia. Acta Amazonica 51: 166-170.

Additionally, nine taxa from the benthic flora of rhodolith beds were described (Vale *et al.* 2018). This diversity is probably underestimated since video surveys reported unidentified crustose algae at depths between 70 to 180 m (Francini-Filho *et al.* 2018).

The Amazon coast and shelf are under recent anthropogenic impacts (Francini-Filho *et al.* 2018). The coast is undergoing a process of urbanization and land-use change, while the shelf is affected by predatory trawling since the 1960s (Isaac and Ferrari 2017) and drillings for oil and gas exploration are eminent (ANP 2020). Knowledge of the diversity of benthic algae is thus urgent because the algae are significant primary producers, hosts of associated invertebrates, builders of rhodoliths and source of pharmacological compounds (Simioni *et al.* 2019).

Here we report a list of benthic algae from three beaches of the coast of Pará, with the first results for algae on rocky outcrops, new occurrences, and range distribution extensions.

Collections occurred on three beaches at the municipalities of Salinópolis (Atalaia beach, on December 7, 2014) and Marapanim (Marudá and Crispim beaches, on March 17 and 18, 2017) (Figure 1). The coast is influenced by a high tidal amplitude, between 4 - 6 m, high salinity variation (17 - 40), but homogeneous temperature throughout the year (29 - 31 °C) (e.g. Danin *et al.* 2020 for Salinópolis). The typical mangrove trees on the northeastern coast of Pará are *Avicennia germinans* (L.) L. and *Laguncularia racemosa* (L.) C.F. Gaertn (Bastos *et al.* 2001).

The Atalaia beach (0°35'35"S, 47°18'50"W) is impacted by a wave height reaching 1.2 m (Ranieri and El-Robrini

2016). At the central portion of the beach, natural rocky outcrops were sampled (Figure 2a). Both Marudá (0°37'29"S, 47°37'51"W) and Crispim (0°35'0"S, 47°39'14"W) beaches are surrounded by mangroves, where the algae were collected (Figure 2b). Abandoned and eroded civil constructions were also sampled at Crispim beach (Figure 2c). Small mangrove patches are distributed at Marudá and Crispim beaches, between tidal channels and sand dunes.

Sampling was performed during the low tide, at the midlittoral sector of the beaches. The algae were removed



Figure 2. Examples of sampled substrates. A – Rocky outcrop (maximum height about 1 m) at Atalaia beach during the low tide; B – Roots and branches of *Laguncularia racemosa* at Marudá beach; C – Crispim beach, with civil constructions as substrata for *Pseudorhizoclonium africanum*.

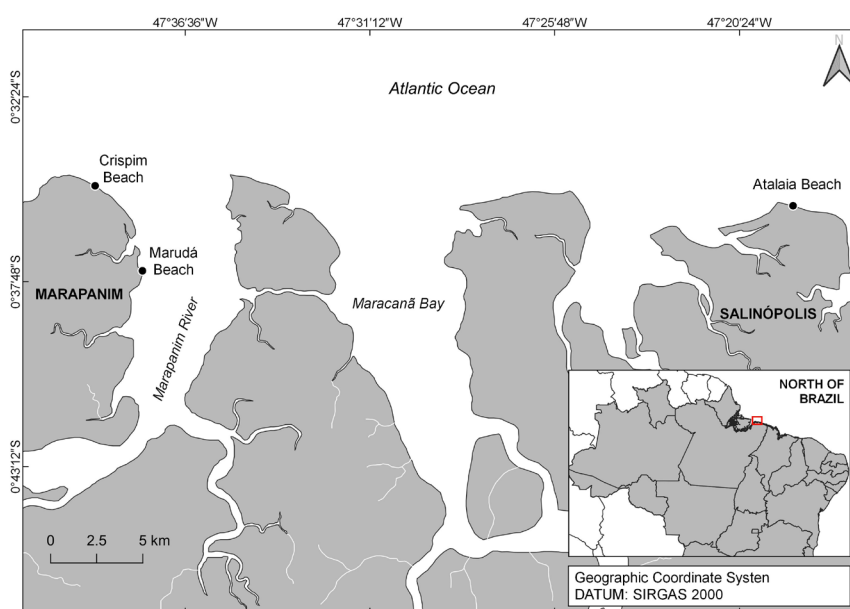


Figure 1. Location of the study area on the northern Brazilian coast, and location of the sampled beaches of Atalaia (Salinópolis municipality), Marudá and Crispim (Marapanim municipality) on the northeastern coast of Pará state.

using stainless steel spatulas and transferred to clean containers with buffered formaldehyde diluted in seawater at a final concentration of 4%. Samples were kept in the dark until analysis.

The systematic classification from Wynne's (2017) checklist was adopted, and the names of the taxa were updated by checking the AlgaeBase database (Guiry and Guiry 2020). Microscopic analyses were made using an optical microscope and a stereomicroscope. Length and width of stems, blades and other structures were measured with an imaging system coupled to the stereomicroscope. Identified voucher specimens were deposited in the herbaria of Universidade do Estado do Rio de Janeiro (HRJ), Universidade de São Paulo (SPF) and Universidade Estadual de Feira de Santana (HUEFS).

The phycological flora was represented by 23 taxa: 12 Rhodophyta (52.2%), nine Chlorophyta (39.1%), one Ochrophyta (4.3%) and one Cyanophyta (4.3%). Most of the taxa (91.3%) were restricted to a single beach, with only two exceptions: *Bostrychia radicans* and *Pseudorhizoclonium africanum* (Table 1). Atalaia had the highest richness with 17 taxa (10 Rhodophyta, six Chlorophyta and one Ochrophyta) and a total of 69.6% exclusive taxa. Six taxa were recorded at Marudá: two Rhodophyta, three Chlorophyta and the Cyanophyta *Coleofasciculus chthonoplastes*. Four taxa (17.4%) were exclusive at Marudá. At Crispim, only four taxa were detected: two Rhodophyta and two Chlorophyta, two (8.7%) being exclusive.

The most representative families from each division were: Cladophoraceae (Chlorophyta) with five taxa (21.7%), Rhodomelaceae (Rhodophyta) with three taxa (13%) and Bachelotiaceae (Ochrophyta) with a single taxon (4.3%) (Table 1). The Rhodophyta *Bostrychia radicans* was the most frequent alga and the only one occurring at all beaches, while *Pseudorhizoclonium africanum* was the only one to occur at both Marapanim beaches. The Ochrophyta were present only at Atalaia, represented by *Bachelotia antillarum*, while small patches of *Ulva linza* were restricted to wood pilings from houses built at Crispim and *Ulva chaetomorphaeoides* was restricted to Marudá. Four epiphytic taxa (17.4%) were found on the sampled macroalgae: *Coleofasciculus chthonoplastes*, *Acrochaetium* sp., and *Erythrotrichia carnea* were observed on *Bostrychia radicans*, while *Stylonema alsidii* was found in association with *Bostrychia moritziana* and *Hypnea pseudomusciformis*.

With 23 taxa reported in this study, there are now 77 taxa of benthic, marine and estuarine algae registered for the northern coast of Brazil (all for Pará and Amapá states), 45 being Rhodophyta, 8 Ochrophyta, 22 Chlorophyta and 2 Cyanophyta. The older publications on the coasts of Pará and Amapá pointed to a low diversity of algae because the area is dominated by mangroves and river mouths (Oliveira Filho

1977; Paula *et al.* 1989), but probably also due to limited sampling.

One of the most complete studies on the distribution of coastal algae for the Brazilian Amazon described 11 taxa for the mangroves of the municipality of Bragança (Fernandes *et al.* 2005), and nearly half of those were also reported here. At the same mangroves, an additional five species of Rhodophyta were recorded, all attached to the pneumatophores of *Avicennia germinans* (Fernandes and Alves 2011). We assume that rocky outcrops were not sampled in earlier studies, as they were not previously mentioned.

The recent increase in richness of benthic macroalgae for the Brazilian Amazon coast is due to sampling of the previously poorly explored rocky outcrops, where taxa such as *Hypnea pseudomusciformis*, *Pterocladia* sp., *Bachelotia antillarum*, *Bryopsis pennata*, *Cladophora coelothrix* and *C. conferta* were detected. The algal diversity in these outcrops is potentially limited by the low salinity of surrounding coastal waters during the rainy season (Lara and Cohen 2006). Another factor contributing to the richness increase is the record of many taxa at the recently mapped Amazon reefs. Genera like *Dictyota* and *Lobophora* were found growing over coral reefs at depths down to 120 m (Moura *et al.* 2016). In addition, a list of nine crustose algae were described as components of the rhodolith beds in the heterogeneous Amazon reef (Vale *et al.* 2018). These discoveries lead us to speculate that the number of algal taxa for the Amazon coast and shelf is underestimated.

Despite the spatial and temporal constrain, our collections resulted in the highest number of coastal and estuarine algal taxa ever reported for the coast of Pará state. This suggests that a standardized, periodical sampling effort for benthic algae along the Amazon coast will possibly result in a much richer dataset and the description of new taxa. Furthermore, the lack of molecular studies, with the exception of the pelagic *Sargassum* (Sissini *et al.* 2017) and the genus *Bostrychia* (Fontes 2012), hinders the identification of a potentially hidden diversity in the phycological community.

The higher richness observed at Atalaia was probably owed to it being the only beach where rocky outcrops were sampled. However, seasonality may also have influenced richness, as sampling at Atalaia occurred by the end of the dry season, when the Amazon plume is retracted, and oceanic intrusion reaches the coast (Moller *et al.* 2010). Saline waters during the previous months would probably allow the colonization by marine taxa like *Bachelotia antillarum*, *Centroceras gasparrinii* and *Gayralia brasiliensis*. Marapanim was sampled during the middle of the rainy season, when the river plume is extended and salinity values may be as low as zero, with an average of 13 ± 6 (Silva and Martinelli-Lemos 2012). These hypotheses should be tested with an appropriate sampling design, as seasonal variability in algae was rarely reported in the region (Fernandes and Alves 2011).

Table 1. Algae collected at the three sampled beaches of the coast of Pará state, Brazilian Amazonia. A : Atalaia; C: Crispim; M: Marudá; HR: herbarium registry; HRJ: herbarium from Universidade do Estado do Rio de Janeiro; SPF: herbarium from Universidade de São Paulo; HUEFS: herbarium from Universidade Estadual de Feira de Santana. A + sign indicates the presence of the algae on the beach.

| Superior taxa | Species | A | C | M | HR |
|--------------------|--|---|---|---|--------------------------------------|
| Rhodophyta | | | | | |
| Acrochaetiales | | | | | |
| Acrochaetiaceae | <i>Acrochaetium</i> sp. | + | - | - | HRJ 12785 |
| Ceramiales | | | | | |
| Rhodomelaceae | <i>Bostrychia moritziana</i> (Sonder ex Kützing) J. Agardh | + | - | - | HRJ 12786 |
| | <i>Bostrychia radicans</i> (Montagne) Montagne in Orb. | + | + | + | HRJ 12785, 12870, 12874, 12882 |
| | <i>Polysiphonia scopulorum</i> Harvey | + | - | - | HRJ 12792 |
| Delesseriaceae | <i>Caloglossa lepieurii</i> (Montagne) G. Martens | + | - | - | HRJ 12788 |
| | <i>Caloglossa confusa</i> Kravesky, J.A. West & M. Kamiya | - | + | - | HRJ 12871 |
| Ceramiaceae | <i>Centroceras gasparrinii</i> (Meneghini) Kützing | + | - | - | HRJ 12789 |
| Erythrotrichiaceae | <i>Erythrotrichia carnea</i> (Dillwyn) J. Agardh | - | - | + | HRJ 1212874 |
| Gelidiales | | | | | |
| Gelidiaceae | <i>Gelidium pusillum</i> (Stackhouse) Le Jolis | + | - | - | SPF 57940 |
| Pterocladaceae | <i>Pterocladia</i> sp. | + | - | - | SPF 57938 |
| Gigartinales | | | | | |
| Cystocloniaceae | <i>Hypnea pseudomusciformis</i> Nauer, Cassano & Oliveira | + | - | - | HRJ 12794, 12793; SPF 57938 |
| Stylonematales | | | | | |
| Stylonemataceae | <i>Stylonema alsidii</i> (Zanardini) K. M. Drew | + | - | - | HRJ 12786, 12793 |
| Ochrophyta | | | | | |
| Ectocarpales | | | | | |
| Bachelotiaceae | <i>Bachelotia antillarum</i> (Grunow) Gerloff | + | - | - | HRJ 12784 |
| Chlorophyta | | | | | |
| Bryopsidales | | | | | |
| Bryopsidaceae | <i>Bryopsis pennata</i> J.V.Lamouroux | + | - | - | HRJ 12787 |
| Cladophorales | | | | | |
| Cladophoraceae | <i>Cladophora brasiliensis</i> G.Martens | + | - | - | HRJ 12790, 12791 |
| | <i>Cladophora coelothrix</i> Kützing | + | - | - | HRJ 12792 |
| | <i>Cladophora conferta</i> P. Crouan & H. Crouan in Schramm & Mazé | + | - | - | HUEFS 219018 |
| | <i>Pseudorhizoclonium africanum</i> (Kützing) Boedeker | - | + | + | HRJ 12868, 12881, 2879, 12878 |
| Siphonocladales | | | | | |
| Boodleaceae | <i>Cladophoropsis membranacea</i> (Hofman Bang ex C. Agardh) Børgesen | - | - | + | HRJ 12872, 12875, 2876, 12877, 12867 |
| Ulvaes | | | | | |
| Gayraliaceae | <i>Gayralia brasiliensis</i> Pellizzari, M.C.Oliveira & N.S.Yokoya | + | - | - | HRJ 12866, 12869 |
| Ulveaceae | <i>Ulva linza</i> L. | - | + | - | HRJ 12883 |
| | <i>Ulva chaetomorphoides</i> (Børgesen) Hayden <i>et al.</i> | - | - | + | HRJ 12865, 12873 |
| Cyanophyta | | | | | |
| Oscillatoriales | | | | | |
| Coleofasciculaceae | <i>Coleofasciculus chthonoplastes</i> (Thuret ex Gomont) M.Siegesmund, J.R.Johansen & T.Friedl | - | - | + | HRJ 12882 |

Our survey resulted in new occurrences and distribution extension for nearly half of the recorded taxa (43.5%). We provide a new record for a Chlorophyta for Pará state only (*Pseudorhizoclonium africanum*), and nine new occurrences for the entire northern coast of Brazil: *Bryopsis pennata*, *Cladophora coelothrix*, *C. conferta*, *Gayralia brasiliensis*, *Ulva chaetomorphoides*, *Caloglossa confusa*, *Centroceras gasparrinii*, *Bachelotia antillarum* and *Coleofasciculus chthonoplastes*.

The new occurrences reported in here resulted in an increase in the benthic, marine and estuarine algal taxa registered for the Pará state coast. Our results suggest that the benthic marine flora diversity of the Brazilian Amazon coast is underestimated, and sampling efforts should be increased to properly assess the diversity and enable the sustainable management of these taxa.

ACKNOWLEDGMENTS

We acknowledge Dr. Sebastião J. S. Neto, for the deposit of voucher specimens at the HRJ herbarium, Dra. Aigara Alves for the revision of *Cladophora*; Dra. Mariana Oliveira and Dra. Cintia Iha, for the identification of *Pterocladia*, our colleagues Thiago Franklin and Pedro Marques, for some of the identifications, Arnaldo F. Queiroz for the map design, and Dr. M. Wynne for scientific revision and English amendments.

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RECEIVED: 24/10/2020

ACCEPTED: 17/02/2021

ASSOCIATE EDITOR: Natalia Ivanauskas



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