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**DIVERSITY OF
MACROALGAE IN
INFRALITORAL ZONES
OF TWO ROCKY COASTS
OF UBATUBA, SP**

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Abstract: The rocky shores are important environments for the balance of coastal ecosystems, because due to the large amount of nutrients coming from terrestrial systems, they present favorable conditions to support great biodiversity. These are the richest areas in macroalgae among all marine ecosystems. The objective of this research was to identify the macroalgae diversity of the rocky shores of Itaguá and Fortaleza beach in the municipality of Ubatuba, São Paulo. The applied methodology was a visual estimate for covering the sample plots with 100 cm² and 400 cm². The bionomic indexes of number of species, the total percentage of the covering and the dominance and diversity index were applied. The results obtained indicated the presence of 8 species of macroalgae in the protected coast of Itaguá and 7 species in the coast of Fortaleza. The similarity between the two shores indicated a percentage of approximately 52.5%. The Shannon (H') index in Fortaleza was 1.8 and in Itaguá 1.65. Pielou (J) equitability in Itaguá was 0.79 and in Fortaleza approximately 0.93. It was seen that in the total of species obtained, the phylum of Rhodophytas was greater represented, corresponding to 50% of the species found, compared to the phylum of Phaeophytas which constituted 20% of the species. Despite having fewer species, brown algae were the most dominant of both beaches, being *Sargassum* sp. the most dominant in Itaguá and *Padina gymnospora* the most dominant in Fortaleza.

Keywords: Diversity indices, Benthic algae, coastal ecosystems.

INTRODUCTION

The rocky shores are clusters of rocks that are found in the intertidal zone of the coast and that are exposed or submerged according to the variation of the tide (CASTRO; HUBER, 2012). It is considered a transition

zone between the marine and terrestrial environment, being defined more as a marine environment as it has great biodiversity linked to the sea (ALMEIDA, 2008).

The rocky shores can be found almost all along the Brazilian coast, with greater predominance in the Southeast region, where the coast is more indented and presents a large part of the proximity to Serra do Mar (COUTINHO, 2002), a fact that favors the predominance of these environments such as takes place in Ubatuba (CETESB,1998).

They are extremely important environments for the balance of coastal ecosystems, as they have a large amount of nutrients from terrestrial systems (NETO; FUJII, 2016), thus comprising a rich and complex biological community, and it is common to find large swaths occupied by several sessile organisms, benthic invertebrates, fish and algae (ALMEIDA, 2008).

Macroalgae are photosynthetic multicellular organisms (with the exception of parasitic species) that mostly live fixed to a solid substrate. Due to this, the rocky shores and bottoms are the richest areas in macroalgae among all marine ecosystems, both in diversity and in biomass (NETO; FUJII, 2016). Based on this knowledge, the importance of studying the algae present in these environments becomes evident, in order to know the local diversity in order to direct studies in the area towards the preservation of places with higher biological indexes.

GOAL

The aim of the study was to identify the diversity of macroalgae from the rocky shores of Itaguá and Praia da Fortaleza located in the municipality of Ubatuba, and to compare the species found in both locations.

MATERIAL AND METHODS

STUDY AREA

The study was carried out in March 2018 on the rocky shores of Itaguá beach (in Caisão) and Fortaleza, in the municipality of Ubatuba, North Coast of São Paulo. The geomorphology of the place indicates that the beaches face the northwest face. Both beaches are located in a protected region of open sea situation (Figure 1).

METHODOLOGY

The method used was the visual estimate, described by Sabino and Vilaça (1998). Two squares were launched with areas of 100cm² and 400cm², subdivided into 25 sub-squares each. In each launch, Sighting and Overlay points were assigned to species within the square's area.

Each square was launched 5 times over infralittoral areas in a random way, in a strip of 100 meters of extension for each coast. The algae present in the inner region of these squares were photographed and samples were collected for further identification in the laboratory, where they were analyzed with magnifying glasses and microscopes and identified with the aid of an illustrated guide (NETO; FUJII, 2016). For the bionomic indices of community structure, the methodology described by Sabino and Vilaça (1998) was adopted.

The results of each location were released in the *PAST Software* to obtain the bionomic indices (BARROS, 2007).

RESULTS

ITAGUÁ

In Itaguá, the presence of 8 species of macroalgae was observed, namely: *Centroceras clavulatum*, *Corallina officinalis*, *Dichotomaria marginata* and *Gelidium floridanum* of the phylum of Rhodophytas (algas vermelhas),

Sargassum sp. and *Padina gymnospora* of the Phaeophyta phylum (brown algae) and algae *Caulerpa racemosa* and *Ulva lactuca* of the phylum of Chlorophytas (green algae).

The Sighting, Overlay and Overlay percentage obtained are presented in table 1.

The results reveal the diversity of macroalgae found and allow us to visualize the most abundant species. Total Overlay values are shown in Figure 2.

The population survey of species from the coast of Itaguá revealed the predominance of the species: *Sargassum* sp., *P. gymnospora* e *D. marginata* (figure 3) respectively.

FORTALEZA

The coast of Praia da Fortaleza is agitated and heavily influenced by the waves. For the 10 random plots launched at this location, 7 species were found and identified, it is them: *C. racemosa*, *Cladophora vagabunda* and *U. lactuca* do filo das Chlorophytas, *Aglaothamnion uruguayense* and *D. marginata* of the phylum Rhodophytas and *Sargassum* sp. and *P. gymnospora* of the phylum of Phaeophytas.

After identification, the algae were accounted for in the same way as those on the Itaguá coast, and the results obtained are shown in table 2.

The total coverage for the species seen on Fortaleza beach are shown in Figure 4.

Of the identified species, it was observed that the most abundant on the Fortaleza coast were: *P. gymnospora*, *A. uruguayense* and *D. marginata* (figure 5). The species: *P. gymnospora*, in the North Coast of São Paulo is very common, mainly on beaten and moderately protected cliffs, such as the Fortaleza cliff.

COMPARISON OF RESULTS

The comparison between the two cliffs was performed by analyzing the geomorphology

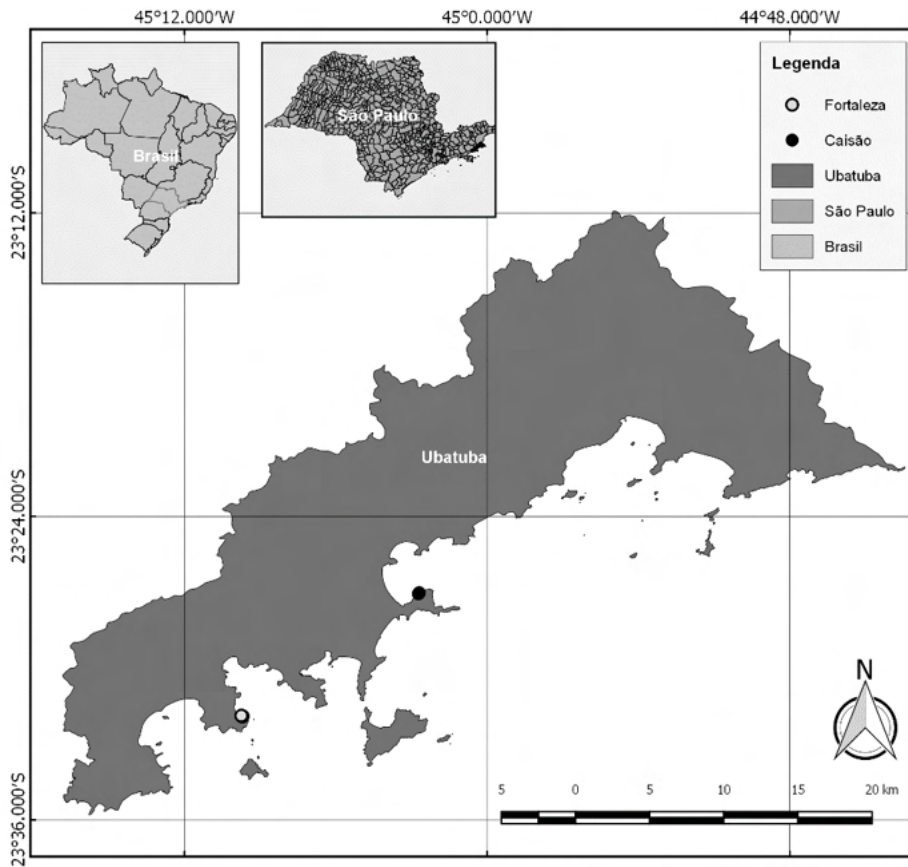


Figure 1 – Geographic location of Itaguá and Fortaleza beaches, Ubatuba-SP
Source: Authors (2020).

Espécie de alga	Square meters - 100cm ²			Square meters - 400cm ²		
	Sighting	Overlay	Overlay (%)	Sighting	Overlay	Overlay (%)
<i>Caulerpa racemosa</i>	0	-	-	10	9	7,2%
<i>Centroceras clavulatum</i>	0	-	-	7	5	4%
<i>Corallina officinalis</i>	15	12	9,6%	18	14	11,2%
<i>Dichotomaria marginata</i>	29	25	20%	20	14	11,2%
<i>Gelidium floridanum</i>	0	-	-	4	4	3,2%
<i>Padina gymnospora</i>	30	24	19,2%	26	21	16,8%
<i>Sargassum sp.</i>	57	51	40,8%	44	35	28%
<i>Ulva lactuca</i>	0	-	-	13	7	5,6%

Table 1 – Diversity of macroalgae on the rocky coast of Itaguá, Ubatuba – SP.
Source: Authors (2018)

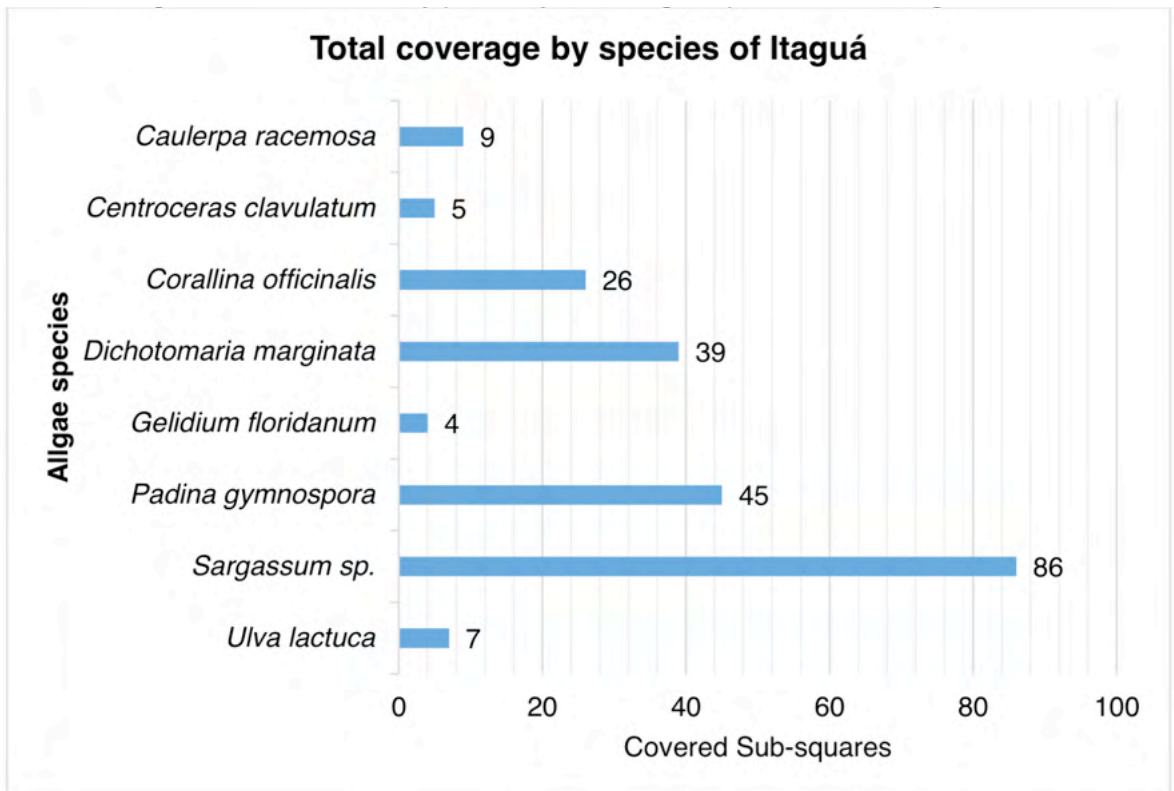


Figure 2: Sum of Overlay points by macroalgae species on the Itaguá coast
Source: Authors (2018)



Figure 3: The three most abundant species in Itaguá. Subtitle: A – *Sargassum sp.* B – *Padina gymnospora* C - *Dichotomaria marginata*.
Source: Authors (2018)

Seaweed species	Square meters 100cm ²			Square meters - 400 cm ²		
	Sighting	Overlay	Overlay (%)	Sighting	Overlay	Overlay (%)
<i>Aglaothamnion uruguayense</i>	19	15	12%	21	14	11,2%
<i>Caulerpa racemosa</i>	14	9	7,2%	5	4	3,2%
<i>Cladophora vagabunda</i>	9	8	6,4%	23	18	14,4%
<i>Dichotomaria marginata</i>	18	16	12,8%	13	12	9,6%
<i>Padina gymnospora</i>	27	25	20%	42	37	29,6%
<i>Sargassum sp.</i>	7	7	5,6%	21	18	14,4%
<i>Ulva lactuca</i>	19	11	8,8%	0	-	

Table 2 – Macroalgae diversity at Praia da Fortaleza, Ubatuba – SP

Source: Authors (2018)

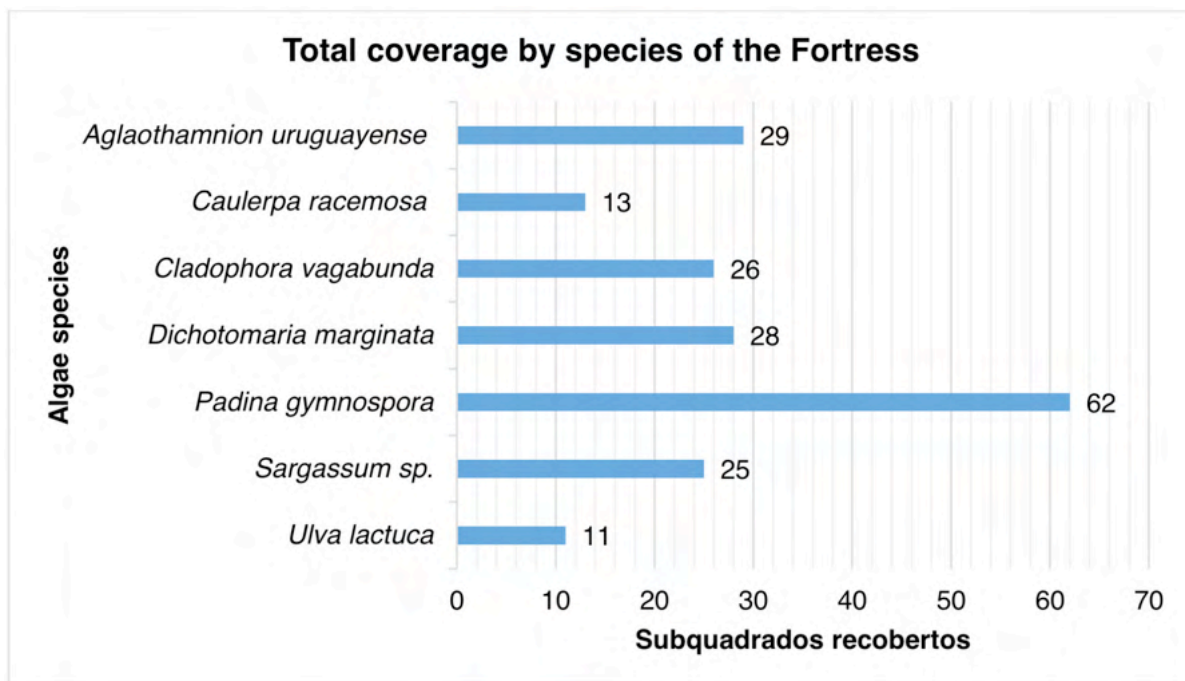


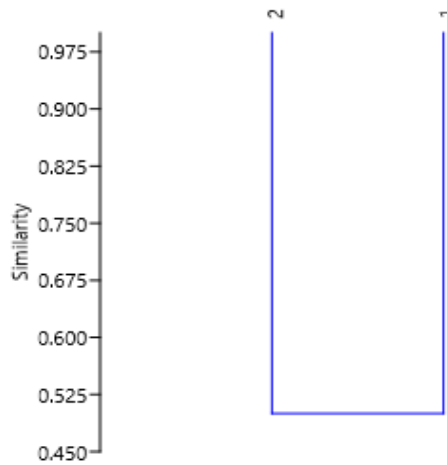
Figure 4: Sum of cover points by macroalgae species on the Fortaleza coast

Source: Authors (2018)



Figure 5: The three most abundant species in Fortaleza. Caption: A – *Padina gymnospora* B – *Aglaothamnion uruguayense* C - *Dichotomaria marginata*.

Source: Authors (2020)



Legend: 1. Itaguá and 2. Praia da Fortaleza

Figure 6: Jaccard similarity cladogram for the two beaches.

Source: Authors, *Software PAST* (2018)

Índexes	Fortaleza	Itaguá
Taxa _ S	7	8
<i>Individuals</i>	194	221
Simpson _ 1-D	0.81	0.76
Shannon _ H	1.8	1.65
Equitability _ J	0.93	0.79

Table 3 - Diversity indices at both study sites

Source: Autores, *Software PAST* (2020)

of each cliff and the diversity indices, which according to Odum (2010) are an approach to analyze the diversity of species in different situations, being important to generate from the results, the classification of species in the components of these indexes, indicating whether the species is dominant, what is the degree of richness and what is the uniformity of distribution in the place.

With the individual results of each location, it was possible to carry out a comparison between the diversity of species. Starting from this point, the Jaccard similarity index was used, which attributes a comparison between the species found on each cliff, generating in percentage the degree of similarity between the locations (Figure 6).

From this result, it was possible to verify that there was a similarity of approximately 52.5% between the species present in the studied areas.

In addition to the similarity, the values obtained were submitted to *Software Past* to calculate the diversity indices (Table 3), in order to obtain the values of the Shannon, Simpson and Pielou evenness indices.

The $rate_S$ indicates the total value of species found, where it was found that Itaguá ($n=8$) had a greater number of species, when compared to Fortaleza beach ($n=7$). The individual index indicates the total value of covered sub-squares and it revealed that in Itaguá the coverage was $n=221$, while in Fortaleza the coverage was obtained with $n=194$.

Simpson's index, which shows the dominance of species, indicates the probability of finding the same species in two random points, so the Fortaleza coast has species with greater dominance, with a value equal to 0.81.

The Shannon index indicates diversity, where the highest value represents the place with the greatest diversity of species, in this case Fortaleza with a value of 1.8, while in

Itaguá $H'=1.65$. Finally, Pielou's equitability, which is the common abundance among species where the value varies between 0 (zero) and 1 (one) and the closer to 1, the greater the uniformity in the distribution of species, thus the coast of Fortaleza it has the greatest uniformity with a value of 0.93.

DISCUSSION

It was observed that most species are the same on both coasts, even in the case of places hit with different intensity by the waves, a fact that determines the distribution of species (SALOMÃO; COUTINHO, 2007). During the research, it was observed that the two beaches are rich in some species of macroalgae, such as *Sargassum* sp., *P. gymnospora* and *D. marginata*, which are abundant species in the region, being found mainly in meso and infralittoral zones, and may occupy large areas (NETO; FUJII, 2016), a fact that was observed in the field.

Eight species of algae were seen in Itaguá and 7 in Fortaleza, but the results of the Shannon index of both beaches showed greater diversity in the Fortaleza coast, which is a beaten coast, which corroborates two studies carried out in 2007, where they concluded that beaten shores present greater diversity of species, which are generally found in greater abundance along the shore (SALOMÃO; COUTINHO, 2007), (SILVA; COUTINHO 2007).

The coast of Itaguá is protected, that is, it does not suffer major disturbances from the waves, making it an ideal shelter for many animals. The disturbance caused by the waves can limit the activity of mobile species, making predation and herbivory activities more constant in protected environments, so this diversity in the fauna makes the development of algae controlled by feeding the animals (SALOMÃO; COUTINHO, 2007).

The Shannon index (H') in Fortaleza was 1.8 and in Itaguá 1.65 and can be compared to a study of macroalgae carried out in Santa Catarina (MARMITT et al., 2015), where they obtained a result of 1,95 for the Shannon index, a diversity value close to that obtained in Fortaleza. Furthermore, in this study they also calculated the Pielou (J) evenness, and obtained a final result of 0.72, while in Itaguá the index was 0.79 and in Fortaleza approximately 0.93. The evenness index was close to 1.0 which suggests homogeneity in the distribution of species on both coasts, indicating the dominance of few species, mainly in Fortaleza, which obtained the highest value.

Of the total species, the phylum of Rhodophytas was represented the highest, corresponding to 50% of the species found, compared to Phaeophytas, which constituted 20% of the species. The same predominance of Rhodophytas was found in the study by Marmitt et al. (2015), with 46.66% representativeness, and also in a survey conducted in Arraial do Cabo, Rio de Janeiro, in 2008, where 71% of the species were red algae (VILLAÇA; YONESHIGUE-VALENTIN; BOUDOURESQUE, 2008).

Considering the individual results of each location, it was seen that in Itaguá there was a predominance of red algae species, 50% of the total identified, while in Fortaleza the predominance was of green algae with 42.85%. The predominance of green algae species is not common, in several studies, such as those by Amado Filho, et al (2003), Gestinari, Nassar and Arantes (1998) and Machado, Nassar and Széchy (2011) the results obtained have always revealed the predominance of species from the phylum of Rhodophyta. Of the articles analyzed, the predominance of green algae occurred only in the study carried out in the Cascavel River drainage basin, in Paraná, where 58.4% of the

species found belonged to the Chlorophyta phylum (KRUIPEK; BRANCO, 2014).

Despite having fewer species, brown algae were the most dominant on both beaches, with *Sargassum* sp. the most dominant in Itaguá and *Padina* gymnospora the most dominant in Fortaleza. A similar fact occurred in a study carried out in the South Coast of Pernambuco, where red algae were the most represented with 46.15% of the species, compared to brown algae with 38.46%, but despite the greater diversity of red algae the site was dominated by *Sargassum* sp (MANSILLA MUNÓZ; PEREIRA, 1998).

Sargassum is the most abundant genus in tropical and subtropical regions, and on rocky shores protected from direct waves, *Sargassum* species are found in greater abundance, forming large banks in shallow sub-coastal zones (ROVER, 2014). This fact corroborates the result obtained in the present research, where on the beaten rocky shore of Praia da Fortaleza only 25 points of coverage were obtained, out of a total of 250, while on the protected shore of Itaguá the population of *Sargassum* obtained 86 points. The genus is present throughout the Brazilian coast and is the most abundant in several places.

CONCLUSION

These ecosystems are of great importance in the conservation of marine environments, as they serve as food and shelter for several species, in addition to being responsible for the high rate of primary productivity.

Protected shores, such as Itaguá, must be further studied in order to carry out a survey of the total biodiversity, both of animals and algae, because, as this is an environment protected from the direct influence of waves, places like this end up becoming rich in biodiversity, having the presence of animals in a more abundant way, thus being excellent points to carry out protection and

environmental education projects.

Studies such as this one, which aim to obtain rocky shore diversity indices, make it possible to quantify the degree of distribution, dominance and diversity of each species, highlighting the biological importance and participation in the functioning of coastal ecosystems, enabling the implementation of environmental protection programs in order to ensure that these environments continue to collaborate with the quality of marine life.

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