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Morphodynamics analysis of the Natural Monument of the Cliffs of Morro Branco, Ceará, Brazil

Análise da morfodinâmica do Monumento Natural das Falésias de Morro Branco, Ceará, Brasil

Delano Nogueira Amaral[1]; Otávio Augusto de Oliveira Lima Barra[2]; Fábio de Oliveira Matos[3]; Cristiano da Silva Rocha[4]; Fábio Perdigão Vasconcelos[5]

[1] Doctoral student of the Postgraduate Program at the Federal University of Ceará (UFC), Campus Fortaleza/Geografia, Fortaleza/CE, Brazil. Email: delanonamaral@gmail.com
ORCID: https://orcid.org/0000-0002-9434-831X

[2] Professor at the State University of Ceará (UECE), Campus Canindé/Geografia, Canindé/CE, Brazil. Email: otavioaolbarra@gmail.com
ORCID: https://orcid.org/0000-0002-8147-8000

[3] Professor at the Institute of Marine Sciences (LABOMAR), Fortaleza Campus/Marine Sciences and Oceanography, Fortaleza/CE, Brazil. Email: fabiomatos@ufc.br
ORCID: https://orcid.org/0000-0003-2215-3780

[4] Doctoral student of the Postgraduate Program at the State University of Ceará, Fortaleza/Geography Campus, Fortaleza/CE, Brazil. Email: crisbandeiras@hotmail.com
ORCID: https://orcid.org/0000-0001-9206-9360

[5] Professor at the State University of Ceará, Fortaleza/Geography Campus, Fortaleza/CE, Brazil. Email: fabioperdigao@gmail.com
ORCID: https://orcid.org/0000-0002-0388-4628

Abstract: Coastal environments are intensely vulnerable, and in the case of the Falésias de Morro Branco, municipality of Beberibe-CE, the disorderly occupation contributes to the realization of risks to the local population, and to the Natural Monument of Morro Branco. The present work aims to analyze the evolution of the morphodynamics of the Natural Monument of the Cliffs of Morro Branco, and to question the use of the land, the elements of interaction of the environment, the risks and the perception of the main agents in the area (Bugueiros and tourism agents). The research used as a basis the first three sub-steps of the ICZM methodology: characterization of the area, definition of management units and data ordering. The morphodynamic analysis was carried out through the use of drone images and photographs during field visits, in addition to the collection of tidal and rainfall data. To analyze the environmental perception, a survey was carried out with buggy drivers and tourism agents, totaling approximately 80 samples. results indicate: rainfall and human occupation as important agents in modifying the geomorphological landscape. Perception data indicates that the main perceived risk comes from mass movement and undermining of occupied slopes, which refers to the need for integrated cost management practices that favor sustainability.

Keywords: Mass Movement; Natural Monument of the Cliffs of Morro Branco; Risks.

Resumo: Os ambientes costeiros apresentam intensa vulnerabilidade, e no caso das Falésias de Morro Branco, município de Beberibe-CE, a ocupação desordenada contribui para a efetivação dos riscos à população local, aos turistas e ao Monumento Natural. O presente trabalho tem como objetivo analisar a evolução da morfodinâmica do Monumento Natural das Falésias de Morro Branco, e discutir o uso do solo, os elementos de interação do ambiente, os riscos e a percepção dos principais agentes sociais atuantes na área (Bugueiros e agentes de turismo). A pesquisa utilizou como base as três primeiras subetapas da metodologia GIZC: caracterização da área, definição das unidades de gestão e ordenamento de dados. Realizou-se a análise da morfodinâmica mediante uso de imagens de drone e fotografias durante visitas de campo, além da coleta de dados de maré e pluviometria. Para análise da percepção ambiental realizou-se pesquisa com os bugueiros e agentes de turismo que totalizaram aproximadamente 80 amostras. Os resultados indicaram: pluviometria e a ocupação antrópica como importantes agentes na modificação da paisagem geomorfológica. Os dados de percepção indicaram que o principal risco-percebido é oriundo do movimento de massa e solapamento de vertentes ocupadas, o que remete à necessidade de práticas de gerenciamento costeiro integradas que favoreçam a sustentabilidade.

Palavras-chave: Movimento de Massa; Monumento Natural das Falésias de Morro Branco; Riscos.

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1. Introduction

Research on coastal management addresses the challenge of preventing or reducing the impacts caused by human action (HALPERN et al., 2010; BARRAGÁN, 2016; SCHERER et.al., 2018). This complexity expands when one of the main economic activities in the municipality of Beberibe is the service sector (IPECE, 2017) with an emphasis on tourism, being a priority sector for the development and generation of jobs in that municipality. Due to various human pressures in this coastal area, the Natural Monument of the Cliffs of Morro Branco was created, through Decree-Law No. 27,461 of 2004 (CEARÁ, 2024).

Despite this initiative, several authors highlight environmental damage and risks in the coastal ecosystems of this municipality, bringing into debate the contrast between the potential weaknesses and problems on the coast of Morro Branco (MEIRELES, 2012; AMARAL et. al., 2020). This scenario does not differ from the national coastal management framework, which does not show signs of positive action (SCHERER et al., 2018). The present work aims to analyze the evolution of the morphodynamics of the cliffs of the Monumento Natural das Falésias de Morro Branco, in addition, it discusses the use of the land and elements of interaction, the risks and the perception of the main social agents operating in the area, such as Bugueiros and tourism agents.

To analyze the morphodynamics, drone images and photographs of the structures were used throughout the field visits, in addition to tide and rainfall data from consolidated research institutes. To analyze the environmental perception of agents who frequent the study area, knowledge of the area and problems was used as a criterion.

Coastal environments with tabular relief with strong slope or decline in the beach strip are also environments that exhibit a risk of high mass movement (SILVA et al., 2020). In general, the cliffs of Morro Branco have a slope classification of cliffs with an inclination > 40º, that is, active cliffs (cliffs), while cliffs with slopes of up to 40º are called *bluffs* (paleocliffs, with greater aerial and subaerial erosion). (DAVIDSON-ARNOTT, 2010).

1.1 Study Area

The Morro Branco Cliffs Natural Monument is located on the east coast of the state of Ceará, approximately 82 km from Fortaleza, in the municipality of Beberibe (Figure 1). The cliffs that are contained in the study area are located in the extreme west of the municipality, as seen in figure 1.

Figure 1 – Location Map of the Research Study Area.
Source: Prepared by the author.

In general, in Ceará we find 573 km of coastline, of which around 36.7 km make up active cliffs (SILVA et al., 2020). The object of this study is a portion of the municipality of Beberibe, east coast, with an estimated population of 54,315 inhabitants. (IBGE, 2021), and with around 10 km of coastline from Morro Branco beach and the set of cliffs that make up the Natural Monument of Falésias de Beberibe. As already mentioned, there is a high potential interaction combined with high demand for occupation, as can be seen in figure 2, which indicates the municipalities preferred by tourists, highlighting the first six (06), with the highest demand throughout the year.

Figure 2 – Favorite destinations in the state of Ceará, with the exception of Fortaleza. Source: Adapted from Ceará (2016).

In general, tourist activities can compromise sustainability through damage to the environment that affects use for current and future generations. In this context, there is a need for studies that contribute to the development of socio-environmental planning and maintenance of sustainable use. This work illustrates a geographical vision of interaction between social and environmental elements and contributes to promoting integrated management of the coastal zone.

1.2 Theoretical basis

In this work, it is understood that socio-environmental relations take place within the landscape, and this can be understood as [...] "a certain portion of space, the result of the dynamic, therefore unstable, combination of physical, biological and anthropic elements which reacting dialectically on each other, make the landscape a unique and inseparable whole, in perpetual evolution" (BERTRAND, 2004, p. 141).

The evolution cited by Bertrand (op. cit.) is related to the changes caused by interaction agents, man organized in society and nature and his structural metamorphosis. In the coastal zone and its subsystems (beaches, mangroves, cliffs, dunes, rocky coast, restinga, lagoons, coves, sandy spits, among others), high potential interactions predominate, which require demand from the lithosphere, atmosphere and hydrosphere (AMARAL et al., 2020; ROCHA et al., 2020).

As mentioned by Nunes et al. (2011), cliffs are made up of cliffs close to the coastline or direct contact with the sea. These are geomorphological features associated with sedimentary rocks (at their base, strongly consolidated sandstone), in the context of northeastern Brazil and are classified as active when strong marine influence erodes the base of the scarp, modifying the structural profile (DINIZ et al., 2010; It is understood that [...] "beaches are deposits of sediment, normally sandy, accumulated by wave action which as they are mobile, adjust to wave and tidal conditions. For this reason, they represent an important element of coastal protection, at the same time as they are widely used for leisure" (MUEHE, 1994, p. 291).

It is notable that the protection of environments in general, and especially environments that exhibit high demand for use and occupation, must be regulated by legislation, and when these environments expose rarity and high vulnerability,

there is a need for more incisive protection. In general terms, the term Conservation Unit (UC) can be understood in light of the SNUC (2000). It is noteworthy that the Natural Monument is a type of Integral Protection Unit, which aims to preserve natural sites, unique or with extensive scenic beauty, requiring, for this, that the areas are made compatible and that the use of the land is carried out in compliance with the management plan, being subject to expropriation and compensation of owners, in case of divergent practices.

Although the legal discourse is in fact coherent, in practice, the set of influences and disputes over the use and occupation of the area make reality chaotic and sometimes private interests overlap, putting the environment, residents and visitors at risk. Considering what Aneas de Castro (2000) mentions, vulnerability estimates the risk in each space. Risk, in turn, is the potential for an adversity to produce negative effects.

It can be seen that the contradictions underlie the existing problems, and these can lead to tragic outcomes, especially when we are talking about an area with a slope in its profile, the presence of unconsolidated materials, which are materials predominantly composed of Tercium-Quaternary sediments of the Barreiras Group (Morais et al., 2018). At its base, it presents consolidated material, but resistance is incompatible with the continuous action of nature, occupation and exploitation of natural resources.

2. Methodology

This research was guided through the first three stages of the GIZC methodology – Integrated Management in the Coastal Zone, which aims to provide a general analysis of the coastal environment (VASCONCELOS, 2005; DINIZ and VASCONCELOS, 2010). The basic premise of this research defends the need for constant monitoring for the implementation of management activities (FUENTES, GRANADOS E MARTINS, 2017), in order to provide effective responses at all administrative levels (UNEP, 2003; UNEP, 2012).

In short, the first stage of the GIZC methodology consists of determining and delimiting the study area, listing problems caused by human action and natural effects; In sequence, the management units related to the problems listed were defined, in addition to listening to and recording the agents involved who experience that space on a daily basis and consultations in newspaper libraries about major events related to the subject addressed. Finally, data was tabulated to qualify and quantify the coastal space. All steps are described in figure 3.

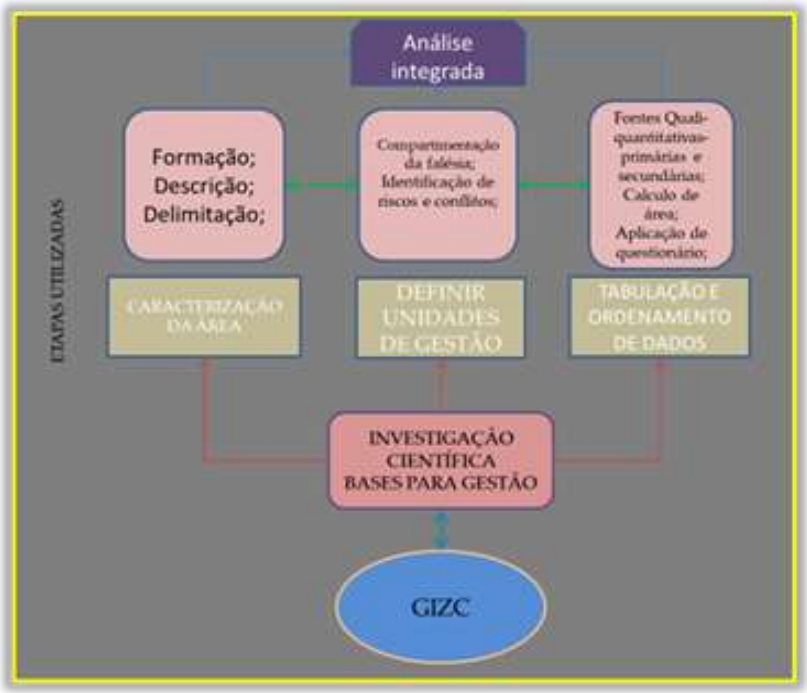

Figure 3 – Flowchart of research steps
Source: Prepared by the author.

Part of this investigation was also guided through the Hypothetical Deductive Method (POPPER, 1975), which points to the act of perceiving gaps or contradictions in presupposed knowledge as a preponderant factor in the investigation (MARCONI AND LAKATOS, 2010). The perspective of creating this method is inserted in a historical context guided by overcoming the clash between empiricism versus rationalism (BARRA et. al., 2020).

The field visit procedures made it possible to analyze the tourist flow, in addition to the application of questionnaires (MINAYO, 2001) with 58 buggies and tour guides who experience the study area daily. Another source of data captured in the field was through remote sensing: recording images through drone flights, the use of RTK Geodetic GPS to capture coordinates and photographic records.

The data production and processing stage provided the production of cartographic materials through drone captures, one of the best remote sensing options today (CAPRIOLI et al., 2015). Data regarding the rainfall regime were based on the Rain Calendar mobile application, provided by the Cearense Foundation for Meteorology and Water Resources – FUNCEME. The information that informs about the direction and intensity of the winds, forecast and data on waves, tide tables, etc., was taken from the Surfguru PRO platform, supplied by the NOAA Global Forecast System, data from the Brazilian Navy and Wheather Underground (METAR), using the Wavewatch III Model.

3. Results and discussion

The changes in the cliffs are quite significant, so that over two years (2020-2021) of analysis, several mass movements were contemplated, that moved large blocks that exceed one meter in diameter. This material is deposited in front of the cliffs, on the abrasion terrace (Figure 4), so that it functions as a protective barrier, mitigating the damage caused by wave attack and, subsequently, participates in the beach's sediment supply (SUNAMURA, 2015).

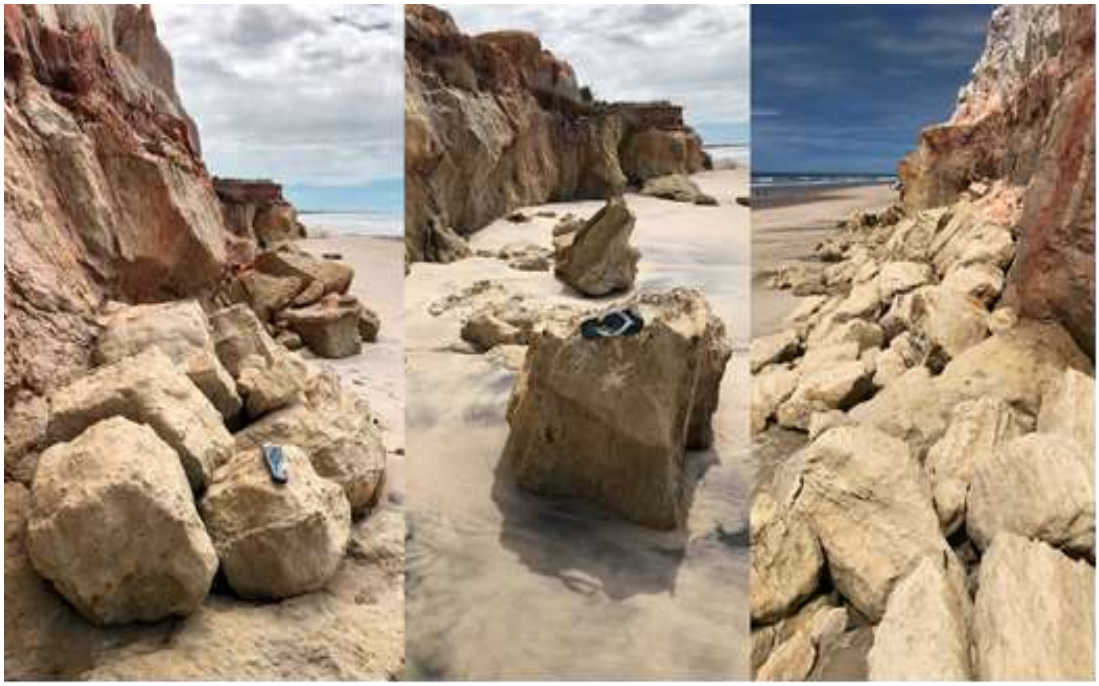

Figure 4 – Large blocks that make up the abrasion terrace after mass movements in Morro Braco. Source: Prepared by the authors, 2021.

This risk of mass movement on the beach, beyond the cliffs, is heightened by debris from destroyed homes in irregular areas, or from the retaining walls that protect summer houses still on site (Figure 5), which in turn, completely distort the rock structures evident on the beach. In addition to the evidence under analysis that points to the risk of accidents similar to what occurred in Pipa, located in the municipality of Tibau do Sul, in the State of Rio Grande do Norte, there was a mass movement event that resulted in the death of three tourists, a couple and a child, who were close to the beach cliffs looking for shade, when the material that hit them was displaced (ZAULI et al., 2020).

Figure 5 – Debris from summer residences located on the Morro Branco beach strip.
Source: Prepared by the authors.

In the context of the Natural Monument of the Cliffs of Morro Branco, one of the most vulnerable agents are the groups of itinerant traders (who live informally), who organize themselves close to the base of the cliffs to sell various products and offer services or guidance, linked tourism in the region (Figure 6). Through field visits, one of these groups reported that they requested the city hall to be able to use that space to carry out their commercial activity, but that this request was not approved.

Figure 6 – Street vendors located close to the cliff structures.
Source: Prepared by the authors.

Despite having their request denied and being aware that they cannot carry out that activity, these traders continue to set up their structures close to the cliffs, claiming that they need to take advantage of the water resources from the natural sources provided by the cliffs - in addition to being a strategic location to attract the attention of tourists. These traders pointed out that they are in that space weekly, and that they had not yet been blocked by inspection agents. Furthermore, traders reported that they are aware of the risks of mass movements, they claim to be aware of this intense dynamic, but they remain in those places seeking subsistence.

It is important to highlight that physical structures such as tents, kiosks and other buildings have already been destroyed previously (AMARAL, 2020). The damage is not exclusively environmental or financial for those who own these fixed assets, but also to the scenic potential of the beach after the events of destruction of the fixed assets (Figure 7) – in addition, obviously, to posing a risk to those trying to save the fixed assets. their assets amid oceanographic events.

Figure 7 – Debris at the seaside of commercial structures on Morro Branco beach destroyed by the sea. Source: Eduard Sweets, 2016.

The intense maritime phenomena, which bring about changes in the area under study, led to the choice of fixed points for a qualitative analysis, contemplating the change in a landscape over a period of five months. Figure 8 shows one of the samples of the erosive capacity of wave undermining against the rigid structure of the base of the cliffs. This significant change occurs in this short period, and it becomes questionable how long the summer resorts located under the cliffs can remain. Following the retreat step by step, in specific spaces, daily used by tourists and local residents, highlights in more depth the risks that disorderly interventions can cause.

Figure (8) (a) and (b) – Sample of the removal of coarse material provided by the mass movement.
Source: Prepared by the authors.

This dynamic does not occur punctually in the samples in evidence, but along the entire chain of cliffs that overlook the Natural Monument, several rocks that exceed one meter in diameter spread along the coast after intense maritime events that intensify the undermining of waves in the structure of the cliffs (Figure 9). No signage or guidance was found throughout these structures regarding the risk of mass movement. However, as previously shown in Figure 5, it is not difficult to find street vendors close to the cliff wall with water spouts nearby, or tourists behind a shade.

Figure 9 (a) and (b) – Structure of the cliffs and the rocky material resulting from the mass movement deposited at the base being compared with a 20 cm object.
Source: Prepared by the authors.

The data collected on monitoring maritime actions indicates both the height of the waves, their period and the force provided by them in joules/m² and kilowatts/per frontal meter of wave. Thus, figure 10 shows a sample of one of the most intense events recorded throughout 2019.

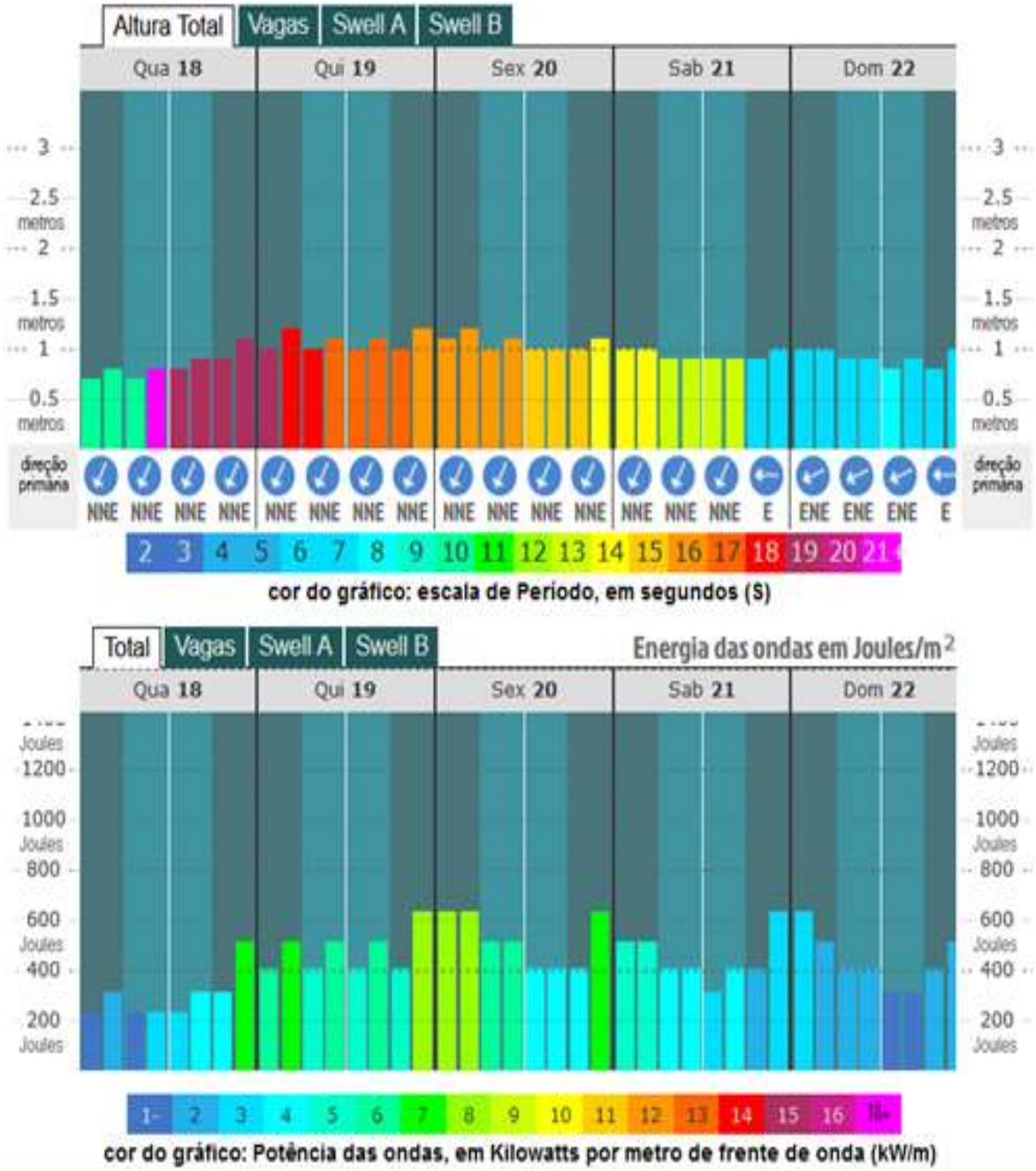

Figure 10 – Sample of one of the most significant events of 2019 on the coast of Morro Branco. Source: adapted from Surfguru (2020).

In figure 10, the period (in seconds) reaches the most intense values provided by the scale (+21), despite having a wave height of around one meter. The predominance of the waves occurs in the N-NE direction and exceeds values of 600 joules, quantifying the intensity of the mechanical force of wave undermining and justifying the mass movements recorded throughout the field visits. The highlighted sample from the year 2020 presents similar, but more intense, characteristics, highlighted in figure 11.

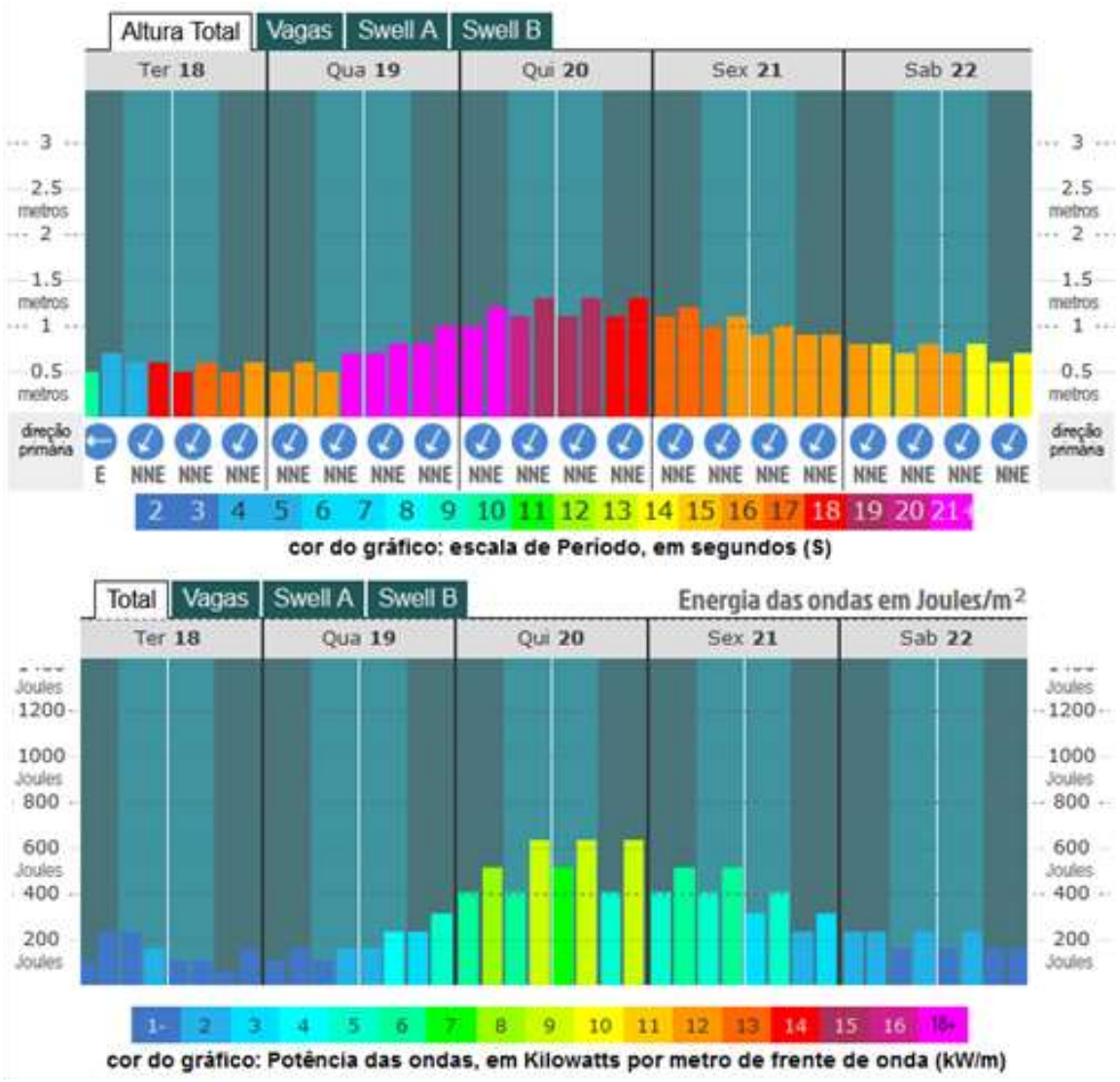

Figure 11 – Highlight sample from the year 2020 on the coast of Morro Branco. Source: adapted from Surfguru (2020).

With waves that reach close to one and a half meters in height, and maintaining the intensity of the maximum period (+21) for longer, the highlight sample from the year 2020 points to the same direction and the same power in joules (but with heights larger). Other events with intensities similar to the samples mentioned occurred over the two years, so Table 2 shows the date of the samples and the average energy intensity of the waves.

It is important to consider that events of "considerable" medium intensity in Table 1 already make the cliffs vulnerable to wave undermining, which implies that the occurrence categorized as medium high, or very high, already increases the possibility of morphogenesis of the structure. Furthermore, it is important to highlight that past phenomena less intense than the samples in figure 12 have already caused damage that destroyed several tents on Morro Branco beach (AMARAL, 2020).

Primeiro Ano de Monitoramento	
2019	
Primeiro Semestre	Segundo Semestre
01/01/2019	27/09/2019
02/01/2019	28/09/2019
03/01/2019	29/09/2019
18/01/2019	12/10/2019
19/01/2019	21/10/2019
04/02/2019	23/10/2019
05/02/2019	29/10/2019
06/02/2019	30/10/2019
10/02/2019	31/10/2019
12/02/2019	01/11/2019
20/02/2019	02/11/2019
21/03/2019	03/11/2019
22/02/2019	04/11/2019
23/02/2019	10/11/2019
24/02/2019	11/11/2019
25/02/2019	22/11/2019
26/02/2019	23/11/2019
27/02/2019	24/11/2019
02/03/2019	25/11/2019
03/03/2019	03/dez/19
10/04/2019	04/dez/19
18/05/2019	05/dez/19
19/05/2019	06/dez/19
20/05/2019	18/12/2019
-	18/12/2019
-	20/12/2019
-	21/12/2019
-	24/12/2019
-	25/12/2019
-	26/12/2019

Segundo Ano de Monitoramento	
2020	
Primeiro Semestre	Segundo Semestre
18/01/2020	20/09/2020
19/01/2020	21/09/2020
20/01/2020	22/09/2020
21/01/2020	26/10/2020
22/01/2020	27/10/2020
23/01/2020	28/10/2020
24/01/2020	29/10/2020
31/01/2020	30/10/2020
01/02/2020	01/11/2020
02/02/2020	02/11/2020
03/02/2020	03/11/2020
04/02/2020	04/11/2020
05/02/2020	05/11/2020
18/02/2020	14/11/2020
19/02/2020	15/11/2020
20/02/2020	16/11/2020
21/02/2020	17/11/2020
22/02/2020	02/12/2020
12/03/2020	03/12/2020
13/03/2020	04/12/2020
14/03/2020	05/12/2020
15/03/2020	08/12/2020
16/03/2020	09/12/2020
17/03/2020	10/12/2020
22/03/2020	11/12/2020
11/04/2020	12/12/2020
12/04/2020	13/12/2020
13/04/2020	14/12/2020
14/04/2020	20/12/2020
24/04/2020	21/12/2020
-	22/12/2020
-	23/12/2020
-	26/12/2020
-	27/12/2020
-	28/12/2020
-	29/12/2020
-	30/12/2020
-	31/12/2020

Média de Intensidade Energética de Erosão das Ondas	
Considerável (entre 250 a 350 jaules)	
Alta (entre 350 a 450 jaules)	
Muito alta (acima de 450 jaules)	

Figure 12 – Monitoring of maritime phenomena and their energy intensity throughout 2019 and 2020. Source: adapted from Surfguru (2020).

Table 2 points out that these events are not merely punctual, therefore, the risks to coastal fixed assets highlighted in past topics occur constantly, as do the geomorphological changes along the coast of Beberibe. The situation presented indicates that the cliffs of Morro Branco are not only alive, but with high erosive intensity due to the combination of different factors, which result in an intensely dynamic environment and, therefore, of high vulnerability. Along with these pieces of data, when asked about the risks within the coastal work environment, buggy drivers and tourism informants pointed out several results summarized in Figure 13.

Figure 13 – The perception of Bugueiros and tourism informants about the risks on the cliffs of Morro Branco. Source: Prepared by the authors.

The 58 volunteers participating in the research indicated that the main risk existing along the Falésias Natural Monument is Mass Movement (66.7%), both on the beach and within the conservation unit. Other points raised were the rocks of the cliffs and remains of buildings resulting from the destruction of walls of summer houses, where each of these points was considered a risk by 26.2% of the participants.

In an open response, only 2.4% of volunteers indicated that they did not perceive any risk in relation to UC. Mass movements do not occur exclusively in the region of the cliffs, but they also suffer intense erosive processes caused by precipitation and wind action – included even in the comments in graph 3. In this sense, throughout the "Labirinto das Falésias" region, a space where the city's main tourist tour takes place and that there are several places of instability due to mass movements, so that the main routes used were specialized in Figure 14.

Figure 14 – Map of trails of the Morro Branco Cliffs Natural Monument.
Source: Prepared by the authors.

The mapping in Figure 14 indicates two large groups of trails, both of which present alternative path options, used by tourists and tour guides at the Falésias Natural Monument. One of the trails is directed more inland, expressed on the map by blue spaces, which is located closer to the fixed dune fields, in order to contemplate the landscape generated by vegetation in rainy seasons and the lighthouse. The other route, the section characterized by the reddish color, commonly used by smaller groups, is closer to the topographic irregularities with narrower and more unstable spaces, where the scenic potential of this section is highlighted by the features of the "Labyrinth of the Cliffs", through a Topographically privileged view that also includes the coast of Morro Branco.

The yellow region shown on the map corresponds to the intersection areas between the two main alternatives, which include movements along the entrance and exit of the walk along the Natural Monument. It is also important to point out that there are other sections and trails that are explored by tourists, such as the Farol Trail and other sections, however, only those routes that are most used by visitors were analyzed here.

Regarding erosion caused by rain, over the two years analyzed, precipitation in Morro Branco was greater than the expected average, when in many cases, a large amount of water was precipitated in a short space of time, intensifying rain events. erosion, mainly throughout 2020, so there are scenarios in which the deviation exceeded twice the expected value (Table 1).

In just a single month, between January and March, the highest rainfall regimes were recorded. In 2019, only in the third month of the year, 462 mm of precipitation were observed, 67% more than the expected average, being the month with the most significant value. Throughout 2021, the most relevant month from a rainfall point of view was February, with 251mm, 123.3% above the expected average. The data that show the negative deviation, mainly "high" values, such as -100%, are linked to months in which the expected average becomes below 10mm, that is, in the absence of rain this percentage masks the data through a high negative percentage, but of little importance.

Table 1 – Rainfall recorded throughout 2019 and 2020.

Precipitação ao longo do ano de 2019			
Mês	**Observado (mm)**	**Desvio**	**Média (mm)**
Janeiro	110,4	-8,50%	110,4
Fevereiro	157,2	28,80%	157,2
Março	462	68,20%	274,6
Abril	262	-12%	297,8
Maio	226	18%	191,6
Junho	45	-52,10%	93,9
Julho	40	23,90%	23,9
Agosto	2	78%	9,2
Setembro	5	42,80%	8,7
Outubro	4	35,10%	3
Novembro	0	-100%	4
Dezembro	8	64,90%	22,8
Total:	1321,6	-	1197,1
Precipitação ao longo do ano de 2020			
Mês	**Observado (mm)**	**Desvio**	**Média (mm)**
Janeiro	248	124,70%	110,4
Fevereiro	351	123,30%	157,2
Março	251	-8,60%	274,6
Abril	350	18%	297,8
Maio	200	4%	191,6
Junho	56	-40,30%	93,9
Julho	36	11,50%	32,3
Agosto	0	-100%	9,2
Setembro	0	-100,00%	8,7
Outubro	0	-100,00%	3
Novembro	7	74%	4
Dezembro	8	64,90%	22,8
Total:	1507	-	1205,5

Source: FUNCEME Rain Calendar, 2021

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Along with the rainfall regime, the route taken by tourists also contributes to intensifying the erosion process and generating mass movements, through the compaction of exposed soil, especially in sections of high slope areas, to take photos, or contemplate the height of the "abyss" (Figure 15). Sometimes, the width of these "corridors" does not exceed 1 meter, meaning there is little space to cover. Furthermore, strong winds can cause imbalances in those traveling through this area. It is important to point out that the period of greatest rainfall intensity is also related to the high tourism season, which contributes to a greater intensity of the risk of mass movements.

Figure 15 – Tourists in risk areas of the UC.
Source: Prepared by the authors.

Mass movements put at risk passages constantly used by tourists and guides (figure 14, red color), so that the traffic space in some locations becomes recurrently reduced, as in Figure 16. It is worth highlighting that in none of these routes are there any signaling about the risk of mass movements, or the like. Furthermore, on many occasions visitors are accompanied by tourism informants from the municipality, especially when this activity takes place in small groups, as seen in Figure 15.

Figure 16 – Sample of a narrow passage area, sometimes used by tourists, or natives, close to areas of mass movement.
Source: Prepared by the authors.

It is important to highlight that the rainfall regime is responsible not only for several mass movements in the Falés ias Natural Monument, but also for the erosion process of the structures where a considerable part of Morro Branco's fixed assets are located. At the beginning of 2021, rainfall of 127mm, in a single day, led to the opening of a gully at the main tourist reception point: the Municipal Crafts Center (Figure 17). After this event, it was necessary to isolate the area, in addition to the evacuation of residents of residences close to the accident site.

Figure 17 – Mass movement at the Morro Branco Craft Center
Source: G1 Ceará, 2021.

These constructions are placed on top of structures similar to the Falésias Natural Monument, which are constantly visited. In fact, the collapse of Figure 17 included an area that was used as a parking lot for tourist buses. This sampling highlights the erosive power of the rainfall regime, not only in mass movements in the UC, but in the real and intense possibility of mass movements in strategic regions of different locations in the district. Through the above, the debate on mass movements in Morro Branco is not restricted to an environmental sphere, or to exclusive limitations of the Natural Monument; Nor should the erosive effects of these areas be limited to oceanographic issues, but this event points to the need to consider the alarming consequences of the intense rainfall regime in a short period, as presented in Table 3 combined with the local landscapes as evidenced in figure 16, together with the testimonies of local tourism agents (figure 13).

4. Final considerations

In light of the above, it was found that in the area of the Falésias de Morro Branco Natural Monument and its surroundings, including urban areas, there are a series of risks and vulnerabilities that need to be considered by the public authorities. In this sense, a set of actions is necessary that may contribute to minimizing this situation highlighted through the results explained.

Mapping and research corroborate the idea that the risk of collapse is not punctual and any fix can compromise natural dynamics, promoting nature's fightback. The rapid effect of the events produces fear in the local community, at the same time the bordering limits and their risks are unknown to tourists.

Geomorphological cartography and data from the cliff in relation to rainfall reveal that on the "safest" trail the area is larger, but the most enchanting scene is the one closest to the cliff and closest to the beach and therefore presents more danger. Inside the cliff flow "rivers" or rainfall channels, linked to the slope potential and the characteristics of porosity, occupation, compaction and power of disintegration through chemical weathering.

Therefore, it is necessary to define specific and official routes to be adopted by everyone, which is incorporated into all tours carried out in the Monumento Natural das Falésias de Morro Branco, which is furthest away from mass movement zones and risk areas. Thus, the present work carried out a mapping that points out the spatial contribution of where visitation actions could be carried out.

Signage strategies must be implemented to provide an awareness-raising environment for everyone who visits the Natural Monument, in order to point not only to collective awareness of environmental care with the UC, but also to highlight the risks present in the conservation unit – mainly to risks facing mass movements. Furthermore, these notices

can accompany technological advances, with QR codes, to generate links to texts, videos, thematic maps and other information mechanisms that promote environmental preservation, sustainable and safe tourism in the municipality.

Concomitantly with this action, the rest of the buildings that already exist on the shore must be removed, which currently cause the beach to become uncharacterized and promote various risks for the transition of buggies and tourists; It is necessary to point out signs about the risks of mass movements, in addition to ensuring together with inspections, that local street vendors and itinerant traders do not settle in these areas.

Furthermore, inspection and monitoring activities on the slopes of the Natural Monument of the Cliffs of Morro Branco must be enhanced during periods of high precipitation, referring to the rainy season, since this factor has been demonstrated throughout the research to be a crucial variable for mass movement, including on cliffs exposed to marine action.

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