SUSTAINABLE MANAGEMENT OF COASTAL ZONES

Sustainable Management of Coastal Zones under pressure

– From Praia de Santo António to Nova Praia –

Report performed by:
Henrique Adelino
Maria Feitor
Mariana Calmão
Mariana Freitas
Martim Esteves

Supervised by:
Professor José Carlos Ferreira
Professor Catarina Jóia Santos

October 2024

Contents

Figure Index

Table Index

1. Introduction

1.1 Characterization of the study area

Costa da Caparica is a region located in the western part of the municipality of Almada, in the Setúbal district, in Portugal. With a sandy beach that stretches for 13 km, this area is bordered to the north by the Tagus River, to the west by the Atlantic Ocean, to the east by Sobreda, and to the south by the municipality of Sesimbra. Notably, this region is one of the few areas along the Portuguese coast that directly faces the Atlantic Ocean without the protection of estuaries or cliffs (Silva & Ferreira, 2013).

This project will be focused on: Santo António da Caparica beach, CDS beach, Tarquínio/Paraíso beach, Dragão Vermelho beach, Nova beach and beach Nova (figure 1). All the beaches included in the study area are classified as urban beaches, type I (Agência Portuguesa do Ambiente, 2018).

Figure 1: Study area. Image obtained through Google Earth software

Until the 19th century, this area was just a small fishing village. Over the years, its natural features and proximity to Lisbon turned it into one of the most sought-after therapeutic destinations in Portugal. Consequently, even before the construction of a bridge over the Tagus River in the 1960s, illegal building, campgrounds, and resorts began to emerge in the dune area. The construction of the 25 de Abril Bridge exacerbated this issue, leading to an influx of more people and vehicles (Palma et al., 2021). Despite the efforts to control and plan the development of this area, Costa da Caparica still suffers from bad planning as well as illegal construction (Câmara Municipal de Almada, 2011).

Currently, Costa da Caparica is characterized by highly sought-after beaches with low seasonality, known for their suitability for nature tourism, sun and sea activities, and nautical tourism (Agência Portuguesa do Ambiente, 2018). The beaches have a high density of beach goers during the summer and surfers during the winter. (Silva et al., 2017). The area is characterized by a dispersed built environment, primarily associated with recreational activities, along with a support zone for precarious fishing activities (Câmara Municipal de Almada, 2011).

Climate can be one of the driving factors for the area's growth, featuring dry and warm summers with temperatures ranging from 23 to 29 degrees Celsius. In winter, temperatures are moderate, dropping to around 6 degrees Celsius in the coldest month (Ferreira, 2016; Ferreira et al., 2021; Da de Oliveira, 2008).

The study area belongs to the sandy low-altitude zone of the Caparica-Espichel coastal section. Geomorphologically, it is composed of dune systems, beach-dune formations, and fossil cliffs (Ferreira, 2016; Ferreira et al., 2021). This area is marked by various alluvial deposits, with materials such as clay, silt, sand, and gravel deposited by the interaction of the Tagus River with the Atlantic Ocean (APRH, 2024) and by the Fossil Cliffs of Costa da Caparica, which are classified as a Protected Landscape under Decree-Law No. 168/84.

This area is primarily characterized by waves ranging from 0.5 meters to 2.5 meters that reach the southwest and northwest regions of the coast. The tidal regime is semi-diurnal, with currents during spring tides that can reach 7.2 km/h and 6.5 km/h during flood and ebb, respectively (Veloso-Gomes et al., 2009).

The beaches of the Costa da Caparica region boast a high diversity of living species. Its flora includes species such as *Ammophila arenaria* and *Pancratium maritimum*, which are endemic to the study area. The region also features species like *Carpobrotus edulis,* which is one of several invasive species observed in the area (Arsénio, 2003). These invasive species have a negative impact on the region as they proliferate relatively easily, ultimately occupying space and utilizing resources that endemic species rely on for their survival, putting their existence at risk (Figure 2).

Figure 2: Dune area occupied by the invasive species Carpobrotus edulis. Photo by the authors.

Vegetation cover on the beaches is not uniform, with areas covered by vegetation in various states of conservation and sections lacking any plant cover (figure 3).

Figure 3: Degraded dune system of the study area. The species Ammophila arenaria and Pancratium maritimum are visible in the images.

Since the second half of the XIX century, and more intensively in the XX and XXI centuries, Costa da Caparica has experienced intense erosive processes, a receding coastline, flooding, and coastal overtopping. These issues have been the focus of various studies and interventions, resulting in the installation of several protective coastal infrastructures (Pereira et al., 2022).

The seawall, which runs parallel to the coastline from Praia do Inatel to the Almada Municipal Camping Club, is one of the most prominent elements in coastal protection (Ferreira et al., 2020; Sancho, 2023). Associated with this structure, six groins have been constructed to mitigate erosion caused by tidal action (Ferreira et al., 2020). Adjacent to the seawall, several beach facilities have been installed (figure 4), which are accessible year-round (Ferreira et al., 2020)
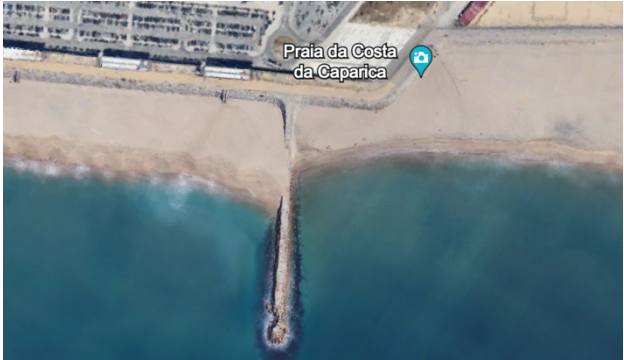
Figure 4: Caffe Espaço20 built on the dune system adjacent to the seawall. Photo by the authors.

The observed trend of coastal retreat has led to artificial beach nourishment operations. These operations use sediments from within the stretch itself (Barra canal) and, although they do not contribute to reducing the sediment deficit, they have helped achieve their primary objective of decreasing coastal risk in the area (Agência Portuguesa do Ambiente, 2018).

However, in the medium term (2050) and long term (2100), it is expected that the rise in average sea level, due to climate change, will create a new sediment deficit, causing the coastal retreat in Costa da Caparica. Therefore, it becomes imperative to direct efforts not only towards artificial nourishment of the system or the construction of gray infrastructures but, more importantly, to seek the relocation of uses and occupations in the areas with the highest vulnerability (Agência Portuguesa do Ambiente, 2018).

Thus, the main issues of the study area are identified, which will be addressed throughout this work (Table 1).

Table 1: Main challenges of the study area. Caffe built on the dunes (a), parking lot adjacent to the dune system (b), coastal overtopping event on the study area (c), receding coastline (d) dune system with waste associated with fishing activity e). Photos (a), (b), (d) e (e) by the authors; photo (c) adapted from Heleno (2017).

Main challenges of the study area	
Compromised Dune Systems Infrastructures built on the dune area, invasive species, unrestricted access to the dune zone, improper use to support fishing activities, and the presence of adjacent roads to the dune area without usage restrictions.	(a)
Encouragement of Vehicle Use Parking lot with 700 spaces adjacent to the dune area.	(b)
Proximity to the Sea Beach support facilities built in areas at risk of coastal overtopping.	(c)
Sediment Deficit	(d)

Main challenges of the study area
Inadequate Waste Management (e)

2. SWOT and TOWS analysis

2.1. SWOT analysis

Table 3: SWOT analysis of the study area

a) Strenghts	b) Weaknesses
• Non industrialized area; • Seasonality; • Existent coastal protection infrastructure;	• Establishments built on the dunes; • Degraded dune ecosystem; • Fishing activity; • Reduced dimension of the beaches.
c) Opportunities	**d) Threats**
• Promote environmental literacy; • Proximity to Nova SST can promote investigation in this area; • Introduction of NBS.	• Tourism growth; • Climate change; • Lack of action by the city council.

a) Strengths

• **Non industrialized area:**

The study area is predominantly residential, with housing and commercial establishments, making it a largely non-industrialized area. This aspect is considered a strength given the various impacts that industry has on the environment, particularly on marine ecosystems.

- **Seasonality:**

    Seasonality is considered a strength from an environmental perspective, as, despite the study area experiencing a high influx of visitors year-round, the number of beach users increases significantly during the bathing season. (Silva et al., 2017).

- **Existent coastal protection infrastructure:**

    The beaches in the study area suffer from chronic erosion, which is why coastal protection measures have been implemented since the early 1970s. Notable among these are gray infrastructures such as the seawall and groins. (Sancho, 2023).

b) Weaknesses

- **Establishments built on the dunes:**
    One of the highlighted weaknesses is the presence of various establishments on the sandy beach, which contributes to the destruction of the dune system. (figure 1a).

- **Degraded dune ecosystem:**

    The study area's dune ecosystem is heavily degraded due to the absence of protection or limitation structures for the dunes. In addition to trampling, the presence of dining establishments (figure 1a), as well as benches, playgrounds (figure 5), and invasive species such as *Carpobrotus edulis*

Figure 5: Playground and benches on the dunes. Photo by the authors.

- **Fishing activity:**

    Another challenge of the study area, particularly on the dune ecosystem, is the presence of fishing activities. Notables are the warehouses and workshops, boats, and waste from fishing activities on the beach (containers, tractors, and fishing gear) (Figure 6).

Figure 6: Waste and fishing boats on the dune system of the study area. Photos by the authors.

- **Reduced size of the beaches:**
  The presence of coastal protection infrastructures, such as the seawall and groins, has not been sufficient to prevent the effects of coastal erosion in the study area. The chronic erosion that the beaches are subjected to results in a reduced sandy area, where interventions such as dune reinforcement are essential. Notably, Portuguese coastal authorities intervened by introducing 4.5 million cubic meters of sand to these beaches between 2007 and 2019 (Sancho, 2023).

c) Opportunities

- **Promote environmental literacy:**
  The promotion of environmental literacy is an opportunity to raise awareness among the public and authorities about the effects of human pressures in the study area. It is important, for example, to educate beachgoers to dispose of their waste in appropriate locations when leaving the beach and to avoid trampling the dunes.

- **Proximity to NOVA SST:**
  The proximity of the study area to Nova SST can constitute an opportunity to promote investigation projects in the study area, namely projects focused on dune restoration.

- **Introduction of NBS:**
  As a complementary solution to the existent grey infrastructure, the introduction of NBS is seen as an opportunity. These alternatives would allow the protection of the population as well as the protection of the dune system. At the same time, these alternatives provide a good cost-effectiveness ratio and allow for the introduction of more natural elements to a landscape that is heavily influenced by anthropogenic elements (Faivre et al., 2017).

d) Threats

- **Tourism growth**
  In 2023, Portugal saw record tourism levels, with over 30 million guests, representing a 10% increase compared to 2019, the previous record year (Diário de Notícias, 2024). Due to its proximity to the capital and for being introduced in the Metropolitan

Area of Lisbon (Pereira et al., 2022), the study area contributes to these statistics. Despite the economic benefits, tourism growth causes diverse impacts in this area.

- **Climate change:**

Sea levels continue to rise at an accelerated rate, and this trend is expected to persist. This factor renders low-lying coastal cities, such as the study area, vulnerable (Griggs & Reguero, 2021), representing a threat to its population and ecosystems.

- **Lack of action by the city council:**

One of the main threats of the study area is the potential lack of action by the city council. The costal and ecosystem protection initiatives can be devalued to the detriment of tourism growth and urbanization.

2.2. TOWS analysis

Considering the strengths, weaknesses, opportunities and threats, the following TOWS analysis was elaborated (table 4):

Table 1: TOWS analysis of the study area

	Strengths	Weaknesses
Opportunities	- Seasonality allows for the introduction of Nature-Based Solutions (NBS) without significantly impacting beach users. - The low industrialization of the area enables the introduction of a wider variety of NBS.	- The proximity to Nova SST could enhance studies related to dune restoration. - Promoting environmental literacy could be an important factor in minimizing the effects of fishing activities in the area. - Dining establishments could benefit from the introduction of Nature-Based Solutions (NBS) considering the improvements in the landscape.
Threats	- The introduction of additional coastal protection elements or the expansion of the sandy area could help mitigate the effects of climate change. - The fact that it is a low-industrialized area may highlight it as an eco-tourism destination	- Mobilization of the local community to urge the municipality to act. - Relocating dining establishments to an area further from the sea would help prevent damage caused by coastal overtopping in winter.

Strengths + Opportunities:

As strategies that leverage strengths to seize opportunities, we highlight seasonality as a strength that enhances the introduction of Nature-Based Solutions (NBS). The lower influx of beach users in winter would allow for studies and the implementation of NBS without impacting beachgoers. Furthermore, the low industrialization of the study area enables the introduction of a greater variety of NBS.

Weaknesses + Opportunities:

As strategies that allow for leveraging opportunities despite weaknesses, we highlight that the proximity of the study area to FCT-UNL enables the development of studies and research projects related to the restoration of the degraded dune ecosystem. Promoting environmental literacy would be a beneficial opportunity for minimizing the impacts of fishing activities in the area, as raising awareness among fishermen could help reduce waste and fishing gear deposition on the dunes. We also note that dining establishments built on the dunes could benefit from the introduction of Nature-Based Solutions (NBS) considering the improvements these alternatives can bring to the landscape.

Strengths + Threats:

The introduction of complementary coastal protection elements to those already in place, including the implementation of Nature-Based Solutions (NBS) and the expansion of the dune area and sandy beach, could help mitigate the threats posed by climate change, such as rising sea levels. Furthermore, the fact that the study area is low in industrialization allows for the reduction of tourism-related threats, as this area can be viewed as a destination for sustainable tourism or eco-tourism.

Weaknesses + Threats:

Weaknesses, such as a degraded dune system, should serve as a catalyst for the local community to urge the municipality to act and prioritize projects focused on dune restoration and area rehabilitation. It is also noteworthy that dining establishments built on the sandy beach would benefit from being relocated further from the coast, considering the damages and losses recorded because of coastal overtopping events in winter.

3. Sustainable Management Strategy

Sustainable management strategies for coastal zones aim at holistic integration and harmonization of various environmental, economic, social, cultural, and recreational sectors. These strategies allow for the enhancement and management of coastal zones by taking advantage of their potential while addressing problems from a sustainable perspective.

Considering this, a sustainable management strategy was developed for the study area covered in this report, from Praia de Santo António to Nova Praia. This strategy seeks to mitigate or solve the previously identified issues by integrating Nature-Based Solutions (NBS), green infrastructure, and the United Nations' Sustainable Development Goals (SDGs) from the 2030 Agenda.

3.1. Goal 1: Rehabilitation of Dune Systems

The degradation of dune systems results from various factors, such as the lack of designated pedestrian pathways leading to uncontrolled trampling, the construction of infrastructures causing soil impermeabilization, and the improper disposal of waste, among others (Pires, 2022). Following observation and analysis of the study area, it became essential to implement strategies aimed at dune rehabilitation.

In this context, Goal 1 - Rehabilitation of the Dune Systems of the Urban Beaches of Costa da Caparica (from Praia de Santo António to Nova Praia) seeks to rehabilitate and preserve the dune ecosystem by rehabilitating existing infrastructures while promoting the sustainable and regulated use of the area. This objective encompasses the following initiatives:

3.1.1.   Measures for Rehabilitation of Dune Systems:

a)   Rehabilitation of the Seawall

The primary goal of the seawall rehabilitation strategies is to implement physical barriers between the concrete seawall and areas of high vulnerability (the dunes), while also removing existing benches from the dunes. Additionally, the construction or restoration of wooden walkways for dune protection is planned. The removal of the seawall is not considered a viable solution due to the high costs involved, as well as its function as a protective structure of the coast (Pereira, 2023).

Targets: The targets for this measure include: (1) the addition of protective barriers delimiting the entire space between the concrete seawall/walkways and the dunes, (2) the removal of all benches located within the dune zone, (3) the rehabilitation of all degraded wooden walkways, and (4) the construction of elevated walkways at strategic points in harmony with the seawall. These walkways will be designed to withstand adverse environmental conditions, such as wind and water erosion, ensuring the longevity of the structures.

Indicators: The success of the strategy will be measured using the following indicators: the percentage of the dune zone perimeter restricted by protective barriers, the percentage of benches removed from the dune zone, and the percentage of walkways installed relative to the total number needed, which will assess the extent of the implemented access infrastructure.

b) Dune restoration

The dune restoration strategy aims at removing non-native invasive species that compromise the dune ecosystem, such as *Carpobrotus edulis*, replanting native species like *Elymus farctus* to restore biodiversity, using stakes to promote the stability and integrity of the dunes, along with artificial nourishment if deemed necessary (Antunes do Carmo, 2006).

Targets: The targets of this strategy include: (1) complete eradication (100%) of invasive plants, (2) introduction of native species essential for dune habitat recovery, (3) placement of stakes to form barriers that assist in retaining wind-transported sand, (4) conducting an annual study to assess the need for artificial nourishment, and (5) artificial dune nourishment if deemed necessary following the findings of target 4.

Indicators: The success of this measure will be evaluated by the following indicators: percentage of invasive species removed from the dune zone, number of native species planted, and the dune size over time (measured in meters).

c) Artificial beach nourishment

Artificial beach nourishment is a coastal defense strategy that proves effective in mitigating erosion while preserving the recreational value of beaches (Pinto et al., 2018).

Targets: The targets of this strategy include: (1) conducting an annual study to assess the need for artificial beach nourishment, and (2) executing artificial beach nourishment if deemed necessary based on the findings of target 1.

Indicators: The success of this measure will be evaluated through the beach size over time (measured in meters).

3.2. Goal 2: Rehabilitation of Anthropogenic Infrastructures

Following the observation and analysis of the study area, it became essential to implement strategies aimed at urban rehabilitation. In this context, Goal 2 – Rehabilitation of Anthropogenic Infrastructures seeks to revitalize and preserve the urban environment in harmony with the natural surroundings provided by the beaches and dunes, while promoting the sustainable and regulated use of space. This objective encompasses the following initiatives:

3.2.1.   Measures for Rehabilitation of Anthropogenic Infrastructures:

a)   Rehabilitation of Fishing-related Infrastructures

This measure aims to delineate the recreational activity area from the surrounding zone of high vulnerability (dunes). This approach seeks to protect fragile dunes while ensuring that fishermen have an appropriate space for their activities. It also aims to reconstruct the existing wooden workshops with materials more resistant to erosion. The area must be carefully planned to maintain accessibility and functionality, providing an efficient and sustainable space for fishing activities.

Targets: The targets of this strategy include: (1) complete delineation of the area using signage, preventing direct access to the dunes by boats, people, or waste from fishing activities; (2) restricting access to the fishing zone solely to vehicles associated with fishing activities; (3) rehabilitating all existing wooden infrastructures, using more durable

materials; and (4) creating specific access routes and pathways for the movement of boats between the sea and land.

Indicators: The success of this strategy will be measured by: the dune size over time (in meters), the percentage of the area occupied by vehicles, and the total number of wooden infrastructures.

b)   Restrict access to the main avenue

The General Humberto Delgado Avenue is considered a focal point for accessing the beaches and the main urban area of the city (Santos, 2001). The influx of vehicles and pedestrians in this area is notably high, primarily due to the significant number of parking spaces and its location within a commercial, residential, and tourist zone. In this regard, the measure to restrict access to General Humberto Delgado Avenue aims to achieve harmonious management of the area (people vs. vehicles), while significantly reducing traffic flow and consequently lowering greenhouse gas emissions.

Targets: The targets of this strategy include: (1) restricting access to the avenue solely to residents and workers with permits; (2) implementing temporary restrictions on vehicle access to the avenue (e.g., hourly and/or seasonal restrictions); and (3) transforming the avenue into a coexistence zone, allowing for simultaneous use by pedestrians and vehicles.

Indicators: The indicators for measuring the success of this strategy include the total number of vehicles accessing the avenue per month.

c)   Rehabilitation of the Parking lot

The Pedro Álvares Cabral and Santo António Beach Parking Lots are located near Santo António and CDS Beaches, behind *Marcelino* Beach Club and Restaurant *O Barbas*. The creation of these parking lots has facilitated an increasing influx of vehicles in the area, as they can accommodate a total of 700 vehicles within less than 1 km. The implementation of this measure aims to reduce vehicle traffic and, consequently, the greenhouse gas emissions at the site. Additionally, it will allow for an increase in space that could be allocated for other infrastructures, such as bars (see measure d).

Target: The target of this strategy involves: (1) reducing the usable area of the parking lot by 50%.

Indicators: The indicator for measuring the success of this strategy is the percentage of the parking lot's area compared to the initial total area.

d)   Relocation of Bars

Throughout the study area, approximately 19 establishments associated with food service or surfing activities are located near the seawall, with most of them built on top of dunes adjacent to the beaches. To preserve existing biodiversity and simultaneously protect

infrastructures and people from the high vulnerability to coastal flooding, it is essential to relocate these establishments to less vulnerable areas, such as urban zones.

Targets: The targets of this strategy include: (1) restructuring the beach concession arrangements by creating an association that integrates the various concessions, (2) relocating the bars to urbanized areas near Avenida Humberto Delgado (between Tarquínio – Paraíso Beach and Nova Praia), and (3) relocating the bars/infrastructures from Santo António Beach and CDS Beach to the space made available through the rehabilitation of the parking lots (measure c).

Indicators: The indicator for measuring the success of this strategy is the percentage of dune area cleared of bars.

3.3. Goal 3: Environmental Literacy

An important way of tackling the problems previously identified in the study area is through behavioral changes, which can be achieved through environmental education. Currently, environmental education can be understood as a way of increasing the public's awareness, knowledge and consciousness of the environment, equipping people with the tools and skills that will enable them to make decisions to adequately tackle environmental problems and contribute to sustainable development (Ferreira et al, 2021). In this sense, Goal 3 on Environmental Literacy includes the following measures:

3.3.1. Measures for Environmental Literacy:

a)   Community Initiatives

The implementation of community initiatives for environmental literacy is fundamental to promoting awareness and education on ecological issues among the population. These programs aim to involve the community in practical and educational activities that encourage the preservation of the environment. Through active participation, citizens develop the essential skills and knowledge to act in a sustainable manner, strengthening the bond between the community and nature, promoting a greener and more conscious future.

Targets: The goals of this strategy involve 1) Informal education through two awareness-raising campaigns promoted by Almada City Council (CMA) in cooperation with non-governmental organizations (NGOs); 2) Organizing four volunteering activities a year; 3) Formal education through training programs.

Indicator: The indicator to measure the success of this strategy includes: Costa da Caparica residents who attend the dynamic sessions (in percentage); number of awareness campaigns per year, volunteer activities and training programs per year.

b)   Informative Signs

The installation of information boards on biodiversity and dune care, for example, is an effective measure to promote environmental literacy. These signs make it possible to educate the community and visitors about the importance of preserving these sensitive ecosystems. Clear and accessible information helps raise awareness about sustainable practices and the protection of local fauna and flora.

Targets: The goals of this strategy involve 1) placing information boards at strategic points to promote environmental respect and responsibility.

Indicators: The indicator to measure the success of this strategy includes: satisfaction of Costa da Caparica residents (using surveys).

4. Critical Analysis of the Sustainable Management Strategy

Despite the numerous benefits that the proposals presented above bring to our study area, there are challenges that make it difficult to apply the proposed measures. The robustness of the measures is not enough to support their implementation, and it is necessary to go through different bureaucratic processes that delay their application.

The bureaucracy involved in implementing measures is one of the main limitations of the Dune Systems Requalification objective. Licensing processes and approvals are major factors that can influence the continuation of the project, especially if there are non-conformities with the legal system. And although there is legislation to reduce administrative bureaucracy (Article 5 of the CPA) and speed up processes, there are other factors, such as the lack of a response within a reasonable timeframe, which can lead to a delay in implementing proposals.

Local resistance can also hinder the implementation of the project, as the community/tourists may not sympathize with the proposed measures, expressing their discontent in various ways (strikes, demonstrations, public petitions), causing a possible delay. In addition, the cost of the project is identified as another crucial factor. The logistical complexity and costs associated with the different measures define the possibility of implementing the projects, and it may not always be feasible to implement the proposals if the monetary investment is exorbitant.

Regarding the upgrading of anthropogenic infrastructures, the problem is associated with the high costs not only of implementing the measures but also of maintenance. Monitoring the project, although essential, can be costly in terms of resources and time, contributing to the delay in achieving the expected results. With access restricted, the local economy may suffer changes and frustrate the expectations of entrepreneurs, reducing public acceptance of the proposed measures. Even during periods of greater tourist intensity, the drop in income could affect many establishments, causing them to close and reducing tourist demand in the places mentioned. The relocation of infrastructures can result in a delay in urban planning, as it is not only necessary to maintain ecological viability, but also economic viability, to guarantee the harmonization of anthropogenic activities with ecosystem services.

The proposals for Environmental Literacy are essential for the proper functioning of a balanced and functional bathing area, but there are some problems with them. Vandalism

can be a limitation of information boards, making their maintenance somewhat costly if public property is destroyed. The receptiveness of the information provided, and its fulfilment also depends on the willingness of visitors to read and apply the guidelines provided. Adherence to community initiatives depends very much on the community in which they are carried out and may or may not be successful or have an effect that is less than expected and necessary for the well-being of the community and the environment.

5. Conclusion

The sustainable management of coastal areas on the Costa da Caparica is fundamental to guaranteeing the preservation of natural resources, the protection of the environment and the promotion of socio-economic development in the region. The implementation of conservation policies, proper waste management and environmental education are essential measures to ensure the sustainability of the coast and guarantee its preservation for future generations.

In this sense, this work has helped to identify the various impacts of human activity in the study area - from Praia de Santo António to Nova Praia - particularly on the dune ecosystem. Given the area's vulnerability to climate change, a strategic coastal zone management plan is urgently needed to reduce the risks to which the community is exposed. However, the implementation of the strategic plan depends on various social, economic and legislative factors.

It is essential that Almada City Council prioritizes the resolution of these problems, so the focus should not only be on economic activities such as tourism. A holistic vision must be adopted that allows the three aspects of sustainability to be combined.

6. Bibliography

Agência Portuguesa do Ambiente. (2018). Programa da Orla Costeira: Alcobaça – Cabo Espichel. Relatório.

Antunes Do Carmo, J. S., Reis, C. S., & Freitas, H. (2006). Successful rehabilitation of a sand dune system. Environmental Problems in Coastal Regions VI, 1, 195–204. https://doi.org/10.2495/CENV060191

Arsénio, P. (2003). *Flora e vegetação da paisagem protegida da Arriba Fóssil da Costa de Caparica* (Provas de Aptidão Pedagógica e Capacidade Científica, Universidade Técnica de Lisboa).

Câmara Municipal de Almada. (2011). Plano de Pormenor das Praias Urbanas. Relatório.

Da de Oliveira, J. A. C. F. (2008). *Na Península de Setúbal, em Finais da Idade Média — Organização do Espaço, Aproveitamento dos Recursos e Exercício do Poder* (Doctoral dissertation, Nova University Lisbon).

Diário de Notícias. 2024. *Turismo alcançou em 2023 o melhor ano de sempre*. Acedido a 25 de Maio de 2024 em https://www.dn.pt/5031830556/turismo-alcancou-em-2023-o-melhor-ano-de-sempre/

Faivre, N., Fritz, M., Freitas, T., De Boissezon, B., & Vandewoestijne, S. (2017). Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges. *Environmental research*, *159*, 509-518.

Ferreira, A. M., Fortes, C. J., Reis, M. T., & Garzon, J. L. (2020). Análise de eventos de risco através de modelação numérica XBeach. Caso de Estudo–Costa da Caparica. In *15º Congresso da Água (submetido)*.

Ferreira, J. C. R. (2016). Ordenamento Ambiental de Frentes Urbanas Litorais em Áreas Baixas de Elevado Risco e Vulnerabilidade ao Galgamento Costeiro. As Infraestruturas Verdes como Estratégia de Resiliência para as Comunidades Costeiras. *Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa*.

Ferreira, J.C.; Vasconcelos,L.; Monteiro, R.; Silva, F.Z.; Duarte, C.M.; Ferreira, F.(2021). Ocean Literacy to Promote Sustainable Development Goals and Agenda 2030 in Coastal Communities. Educ. Sci., 11, 62. http://doi.org/10.3390/

Ferreira, J. C., Cardona, F. S., Jóia Santos, C., & Tenedório, J. A. (2021). Hazards, vulnerability, and risk analysis on wave overtopping and coastal flooding in low-lying coastal areas: The case of costa da caparica, Portugal. *Water*, *13*(2), 237.

Griggs, G., & Reguero, B. G. (2021). Coastal adaptation to climate change and sea-level rise. *Water*, *13*(16), 2151.

Heleno, A. J. P. (2017). *Avaliação do espraiamento e inundação nas praias da Costa da Caparica: modelação com o modelo XBEACH* (Doctoral dissertation, Instituto Superior de Engenharia de Lisboa).

Palma, M., Dias, J. A., & Freitas, J. G. D. (2021). It's not only the sea: A history of human intervention in the beach-dune ecosystem of Costa da Caparica (Portugal). *Journal of Integrated Coastal Zone Managment*, *21*, 227-247.

Pereira, O. N. A., Bastos, M. R., Ferreira, J. C., & Dias, J. A. (2022). Is the Sea the Enemy? Occupation and Anthropogenic Impacts at Costa da Caparica (Portugal). *Water*, *14*(18), 2886.

Pinto, C. A., Silveira, T., & Teixeira, S. B. (2018). Alimentação artificial de praias na faixa costeira de Portugal continental: Enquadramento e retrospetiva das intervenções realizadas (1950-2017). https://doi.org/10.13140/RG.2.2.24446.48969

Pires, P. A. S. (2021). Restauro Ecológico De Sistemas Dunares Sob Pressão [Dissertação para obtenção do Grau de Mestre em Engenharia do Ambiente Perfil de Engenharia de Sistemas Ambientais]. Universidade Nova de Lisboa - Faculdade de Ciências e Tecnologias.

REOT. (n.d.). Planos Diretores Municipais. Direção Geral do Território. Acedido a 2 de junho de 2024, em https://reot.dgterritorio.gov.pt/sistema-de-gestao-territorial/pdm

Sancho, F. (2023). Evaluation of Coastal Protection Strategies at Costa da Caparica (Portugal): Nourishments and Structural Interventions. *Journal of Marine Science and Engineering*, *11*(6), 1159.

Santos, M. D. B. dos. (2021). Costa da Caparica, o espaço público e as novas hierarquias: Caso de estudo: Rua dos Pescadores [Dissertação de mestrado, Iscte - Instituto Universitário de Lisboa]. Repositório do Iscte. http://hdl.handle.net/10071/24008

Silva, S. F., & Ferreira, J. C. (2013). Beach carrying capacity: The physical and social analysis at Costa de Caparica, Portugal. *Journal of Coastal Research*, (65), 1039-1044.

Silva, S. F., Martinho, M., Capitão, R., Reis, T., Fortes, C. J., & Ferreira, J. C. (2017). An index-based method for coastal-flood risk assessment in low-lying areas (Costa de Caparica, Portugal). *Ocean & coastal management*, *144*, 90-104.

Santo, F., Geral, P., Gerais, P., Barroso, P., & Pacheco, D. (2006). 3. O sistema de gestão territorial em Portugal Continental à escala local. 145–164.

Veloso-Gomes, F., Costa, J., Rodrigues, A., Taveira-Pinto, F., Pais-Barbosa, J., & Neves, L. D. (2009). Costa da Caparica artificial sand nourishment and coastal dynamics. *Journal of Coastal Research*, 678-682.