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Natália Ramos Corraini

HIERARQUIZAÇÃO DE ÁREAS PRIORITÁRIAS PARA A GESTÃO DA ORLA MARÍTIMA DA ILHA DE SANTA CATARINA

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Natália Ramos Corraini

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Natália Ramos Corraini

HIERARQUIZAÇÃO DE ÁREAS PRIORITÁRIAS PARA A GESTÃO DA ORLA MARÍTIMA DA ILHA DE SANTA CATARINA

O presente trabalho em nível de mestrado foi avaliado e aprovado por banca examinadora composta pelos seguintes membros:

Prof. Dr. Eduard Ariza
Universidad Autonoma de Barcelona

Prof. Dr. João Nicolodi
Universidade Federal de Rio Grande

Certificamos que esta é a **versão original e final** do trabalho de conclusão que foi julgado adequado para obtenção do título de mestre em Oceanografia.

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CPF: 805.160.419-91

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Prof. Dr. Paulo Pagliossa
Coordenador do Programa

Documento assinado digitalmente
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Profa. Dra Marinez Eymael Garcia Scherer
Orientadora

Florianópolis, 08 de setembro de 2020.

Este trabalho é dedicado a todas as mães cientistas que seguem ainda que na contracorrente.

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“Every individual has a responsibility to contribute to the protection of the environment, in the interests of his or her own health and the health of others”

(World Health Organization , 2000).

RESUMO

Ecossistemas costeiros têm sido pressionados por ameaças antrópicas e naturais. A pluralidade de atividades e usos humanos na planície costeira sujeita a eventos climáticos extremos cria um espaço potencialmente conflituoso, onde se faz necessária a atuação do poder público. Na medida em que os Serviços Ecossistêmicos se configuram como um indicador do estado de qualidade ambiental, torna-se fundamental considerá-los nas tomadas de decisão que envolvam atividades e usos humanos em ecossistemas. A Matriz de Serviços Ecossistêmicos da Ilha de Santa Catarina foi adaptada elencando todos os serviços e benefícios oferecidos pelos ecossistemas da orla marítima da Ilha. Além disso, a análise de risco aos ecossistemas e seus serviços, reconhecida internacionalmente como instrumento de suporte às tomadas de decisão, foi modelada através do *software* InVEST, com seu modelo de avaliação de risco ao hábitat. Considerando os eventos extremos recorrentes na Ilha nos últimos anos, os dados de risco foram associados a dados de susceptibilidade à erosão costeira obtidos do estado da arte, entendendo que áreas com maior risco e sujeitas à ocorrência de erosão demonstram uma maior necessidade de intervenção por parte da administração pública. Desta forma, uma média entre risco e susceptibilidade gerou *hotspots* de áreas prioritárias para gestão. A modelagem indica uma maior quantidade de ecossistemas praiais sob risco muito alto na porção norte da ilha, afetando 19 serviços. Para a floresta ombrófila, os valores altos correspondem ao norte (setor 3), leste (setor 5) e ao sul (setor 6), ameaçando 32 serviços. Dunas apresentam risco muito alto ao norte, ameaçando 18 serviços. O banhado, ecossistema com menos cobertura de solo na área de estudo, possui uma parcela sob risco muito alto no setor 5. Na restinga, o risco muito alto é indicado especialmente no norte, leste e sul (setores 3, 4, 5 e 6), afetando 30 serviços. Os resultados do risco gerados pelo modelo, em associação com a susceptibilidade à ocorrência de eventos erosivos apontaram 14 pontos classificados com risco muito alto, distribuídos ao longo de 7 praias, especialmente no norte da Ilha (setor 3). Recomenda-se o uso dos instrumentos de suporte à gestão disponíveis, especialmente o Plano de Gestão Integrada da Orla, para o estabelecimento de *setbacks* nas áreas ameaçadas, resguardando os ecossistemas, destacando os serviços ecossistêmicos relacionados à proteção costeira contra eventos extremos.

Palavras-chave: 1.Gerenciamento Costeiro 2. Gestão de Praias 3. Serviços Ecossistêmicos 4. Risco. 5. Erosão Costeira.

ABSTRACT

Seashore are the most pressured areas by the presence of activities and by occupation without planning. Conversely, this activities are important for social and economic development and the maintenance of it depends essentially on the Ecosystems and their services. Santa Catarina Island is located in Brazil and have a extensive infrastructure in order to meet the demands of sun and beach tourism. At the same time, coastal erosion events have been increasing. Ecosystem services risk analysis is recognized as an instrument to support decision-making. Ranking priority areas for management according to the risk of ecosystems and the susceptibility of the occurrence of erosion processes favoring most assertive public policies. The classification of Ecosystem Services was made with CICES V.05. Risk analyses was modeled by software InVEST, with Habitat Risk Assessment, considering two major threats: tourism and urbanization. It was related to geoindicators points who indicates erosion susceptibility. A greater number of beach at very high risk in the northern portion of the island, affecting 19 services. For the rainforest, the high values correspond to the north, east and south, threatening 32 services. Dunes present a very high risk in the north, threatening 18 services. The wetlands has a very high risk portion in east. In the restinga, the very high risk is indicated especially in the north, east and south affecting 30 services. The results pointed out 14 classified priority management areas distributed along 7 beaches, especially in the north of the Island. The use of available management support instruments is recommended, especially the Shoreline Management Plans, for the establishment of setbacks in threatened areas, protecting ecosystems and their services, in particular to those related to coastal protection against extreme events.

Keywords: 1. Coastal management 2. Beach management 3.Ecosystem Services 4. Risk 5. Coastal erosion.

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LISTA DE ABREVIATURAS E SIGLAS

HRA Habitat Risk Assessement

IBGE Instituto Brasileiro de Geografia e Estatística

ISC Ilha de Santa Catarina

InVEST Integrated Valuation of Ecosystem Services and Trade-offs

MSEISC Matriz dos Serviços Ecossistêmicos da Ilha de Santa Catarina

PAERV Parque Estadual do Rio Vermelho

PGI Plano de Gestão Integrada da Orla Marítima

PNGC Plano Nacional de Gerenciamento Costeiro

SE Serviços Ecossitêmicos

SUMÁRIO

1 INTRODUÇÃO

A ocupação do território brasileiro deu-se preponderantemente em sua faixa litorânea, onde reside atualmente 72% da população e onde estão situados três dos maiores centros urbanos do país, o que faz com que 70% do PIB nacional estejam concentrados nela (SOUZA, 2009). É também no litoral que estão os os 11,6% remanescentes de Mata Atlântica que ainda ocupam o território brasileiro (RIBEIRO et al. 2009, SOUZA, 2009).

Regiões costeiras de todos os países confrontam uma realidade semelhante, de ecossistemas sensíveis ocupando o mesmo espaço onde há uma concentração de atividades econômicas de grande importância (BARRAGÁN e ANDRÉS, 2016; GRUBER; BARBOZA; NICOLODI, 2003; SCHERER et al., 2009; SCHERER; e ASMUS, 2016).

A manutenção e o funcionamento dos ecossistemas dependem fundamentalmente de sua estrutura (GUERRY, 2018). A pressão por sobre os sistemas ambientais, traduzidos na modificação e conversão dos hábitats, na poluição e pelo aumento da demanda pelos recursos costeiros, vem ocasionando a perda e a diminuição da oferta de Serviços Ecossistêmicos (SE) oferecidos pelos ecossistemas costeiros e marinhos (AGARDY; DAVIS; SHERWOOD, 2011; GRUBER; BARBOZA; NICOLODI, 2003; MARTÍNEZ et al., 2007; SCHERER; ASMUS, M., SANCHES; POLETI, 2009), resultando no decaimento do bem-estar humano e da qualidade de vida nestas áreas, onde uma série de serviços e bens de grande importância são oferecidos (MARTÍNEZ et al., 2007).

Outra ameaça significativa à Zona Costeira são os processos erosivos, que tem sido acelerados pelas ações antrópicas, amentando o risco aos ecossistemas e à infraestrutura existentes nela (CHARLES, 2008; WILLIAMS et al., 2018)

Este cenário de pluralidade de atividades e usos humanos na orla costeira modificando-a, cria um espaço potencialmente conflituoso, onde se faz necessária a atuação do poder público na mediação entre os atores e setores envolvidos (DIEGUES, 2001).

A gestão costeira, através do planejamento, da gestão e do conhecimento dos ambientes naturais e dos processos neles envolvidos, apresenta respostas em forma de ações, políticas públicas e mecanismos estratégicos que possibilitam a transformação do cenário atual de conflitos e perda de serviços (WILLIAMS et al., 2018).

Tendo demonstrado resultados satisfatórios, a análise de risco das atividades e usos humanos aos ecossistemas, e a determinação de zonas de risco intenso é concebida como ferramenta de apoio à gestão, auxiliando no direcionamento das políticas públicas (LONG; CHARLES; STEPHENSON, 2015).

No contexto do Plano Nacional de Gerenciamento Costeiro, instrumento brasileiro norteador para o ordenamento da Zona Costeira, a análise de risco fornece um suporte para o estabelecimento de metas e ações para que a Zona Costeira se desenvolva através dos usos, mas também da conservação dos recursos e ecossistemas existentes (BRASIL, 1988).

Complementarmente, os instrumentos da legislação dão suporte legal para o alcance dos cenários futuros desejados. A depender da instituição responsável pela gestão e da escala de implementação da tomada de decisão, a gestão do risco resulta em diferentes graus de efetividade (STELZENMÜLLER et al., 2018), sendo um processo de melhora constante.

Na orla marítima, esta faixa de ligação entre ambiente terrestre e marinho contida na Zona Costeira (BRASIL, 2004), a análise de risco e a determinação de *hotspots* de risco são uma ferramenta de suporte à gestão no âmbito municipal.

O planejamento, ordenamento e a fiscalização da orla brasileira são de responsabilidade dos gestores municipais, muito embora a área seja patrimônio nacional gerido pela Superintendência do Patrimônio da União (SPU). Desde 2015, a partir da Lei 13.240, a SPU tem a possibilidade de transferir a responsabilidade de gestão para o município, a partir da assinatura de um Termo de Compromisso com duração de 20 anos (BRASIL, 2015). A gestão da orla, portanto, tem como principal instituição a administração pública municipal.

Considerando as atividades e usos humanos recorrentes na orla marítima da Ilha de Santa Catarina, os ecossistemas existentes e os processos erosivos cada vez mais recorrentes, o presente trabalho buscou apresentar a relação entre os ecossistemas e os usos humanos existentes na orla marítima da ISC, objetivando delinear o cenário atual de risco aos ecossistemas, intensificado pela susceptibilidade da ocorrência de erosão costeira, definindo assim áreas prioritárias para a gestão. Esta análise pretende subsidiar uma gestão pró-ativa, que propicie a continuidade da manutenção e oferta dos serviços ecossistêmicos, bem como dos ecossistemas em si.

1.1 OBJETIVOS

1.1.1 Objetivo Geral

Diagnosticar áreas prioritárias para respostas de gestão na orla marítima das porções norte, leste e sul da Ilha de Santa Catarina.

1.1.2 Objetivos Específicos

a) Caracterizar os usos e atividades antrópicas que são vetores de pressão sobre a orla da ISC;
b) Definir o risco que os usos e atividades oferecem aos ecossistemas e seus serviços;
c) Hierarquizar áreas prioritárias a partir de *hotposts* de risco;

2 ARTIGO CIENTÍFICO: Coastal ecosystems risk assessment: ranking priority areas for seashore management in Santa Catarina Island, Brazil

ABSTRACT

Shorelines are the most pressured areas by the presence of activities and occupation without planning. Conversely, these activities are important for social and economic development. The Island of Santa Catarina is located in southern Brazil and has extensive infrastructure to meet sun and beach tourism demands. At the same time, coastal erosion events have increasingly affected the shoreline and its activities. Risk analyses of ecosystem services are recognized as a tool to support decision-making. Ranking priority areas for management according to risk and susceptibility to the occurrence of erosion processes allows more assertive public policies. This work aimed at ranking priority areas for seashore management based on the ecosystems' risk analysis, as well as the susceptibility to erosive processes In the present study, ecosystem services were classified based on the CICES V.05. Risk was modeled using the Habitat Risk Assessment model of the InVEST suite, considering two threats: tourism and urbanization. Data on these threats was combined with geoindicators regarding erosion susceptibility. The results indicated a greater number of beaches at very high risk in the northern portion of the island, affecting 19 services. For the rainforest, high values were found to the north, east and south, threatening 32 services. Dunes presented very high risk to the north, threatening 18 services. Wetlands were at very high risk to the east. Regarding restinga, very high risk was found especially in the north, east and south affecting 30 services. Fourteen priority management areas were defined along 7 beaches, especially in the northern portion of the island. Management support instruments that are already available should be applied, especially Shoreline Management Plans, to establish setbacks in threatened areas, protecting ecosystems and their services, especially those related to coastal protection.

Keywords: 1. Coastal management 2. Beach management 3. Ecosystem Services 4. Risk 5. Coastal erosion.

Introduction

Shorelines are among the most pressured areas by the presence of diverse activities and by unplanned human occupation (Portz et al., 2014; Williams and Micallef, 2009). These include aspects such as tourism, fisheries, aquaculture and infrastructure, which are important factors for the social and economic development of all countries with a coastal zone. The maintenance of these activities depends essentially on environmental quality and the use of ecosystem services (ESs) delivered by healthy ecosystems present in coastal areas (Martínez et al., 2007; Ministry of Tourism in Brazil, 2010).

The intensification of coastal zone occupation brings the need for an infrastructure network that meets population demands. On the other hand, an increase in the occurrence of extreme events in the coastal zone in recent years, worsens as rigid structures occupy the shoreline. The recovery of natural ecosystems that are already threatened by urbanization is further hindered by coastal erosion and other consequences of extreme climate events (Bonetti et al., 2018; Souza, 2009).

Currently, 70% of the world's sandy beaches are undergoing erosional processes (Mori et al., 2010). In these places, the threat to coastal ecosystems is magnified by the overlap with activities and uses that transform natural environments (Ruberti et al., 2017; Williams et al., 2018).

This scenario of diverse human activities on the coast creates a potentially conflicting space, which requires government mediation between stakeholders and socioeconomic sectors involved (Diegues, 2001).

The relationship between natural environments, economic activities and the absence of effective public policies leads to a scenario with conflicts of use and ecological, social and economic losses.

Research tools that characterize ecosystems, stakeholders, activities and local uses allow managerial actions through public policies that are more assertive (Agardy et al., 2011; Grumbine, 1994). Also, to maintain the support for economic activities in coastal zones, as well as their ecological function, it is essential to have a scientific basis and to make decisions in accordance with governance (Martínez et al., 2007).

As ESs are understood as environmental quality state indicators (Böhnke-Henrichs et al., 2013; Sardá et al., 2015), it is fundamental to consider them in decision-making involving human activities and ecosystems (Chan and Ruckelshaus, 2010). Efforts in the use of ESs to support decision-making have been directed towards the development of valuation and modeling tools (Leslie & Mcleod, 2007).

Under these circumstances, ecosystem services risk analyses have shown to be a subsidy tool for management (Sharp et al., 2016). The Integrated Coastal Management Plan of Belize, for example, was developed based on a series of models, among them, a risk analysis (CZMAI, 2016).

Highlighting the places where ecosystems are most at risk allows public authorities to concentrate efforts and resources in areas that are most affected by human activities (Arkema et al., 2014). Also, assessing areas where there is coastal erosion susceptibility allows the same analysis of areas most affected by extreme events. Thus, it is possible to determine areas where specific actions for shoreline management are necessary, ranking priority areas for management according to the protection of ecosystems and their services, favoring the choice of the most assertive public policies.

When it comes to shoreline management and beach management practices, the most frequent responses worldwide are focused on tourism and, more recently, emergency coastal protection (Williams and Micallef, 2009). Thus, ranking priority areas using criteria that consider ecosystems and their services, as well as coastal erosion, expands the scope that provides the basis for shoreline management.

Brazilian territory occupation took place mainly along the coast, and currently 72% of the country's population resides there, with three of the largest urban centers in Brazil and concentrating 70% of the national Gross Domestic Product (GDP) (Souza, 2009). Besides, these densely occupied areas overlap with 11% of the original area occupied by the Atlantic Forest, which provides numerous ESs (Ribeiro et al., 2009).

Brazilian Federal Decree No. 5,300/2004 includes a chapter dedicated exclusively to shoreline management, in which the main planning instrument is the Orla Project and its Shoreline Integrated Management Plan (of the acronym in Portuguese, PGI, *Plano de Gestão Integrada*), although its implementation has not

been ideal so far (Oliveira and Nicolodi, 2012). Since it is an instrument for planning and ordering the shoreline, management goals must be listed. However, there are still few technical criteria that support its operation.

The objective of the present study was to rank priority areas for shoreline management based on an ecosystem risk analysis and on susceptibility to erosive processes.

Materials and Methods

Study Area

The Island of Santa Catarina (ISC) is part of the municipality of Florianópolis, in the state of Santa Catarina, Brazil, with a population of 421,240 inhabitants spread over a total area of approximately 675 km^2 (IBGE, 2013).

The study area selected (Figure 1) encompasses 100 beaches. Only beaches that were considered exposed to incoming waves were considered. Thus, the beaches of the north and south bays of the island were excluded from this study. The shoreline of the municipality of Florianópolis is divided into eight sectors, five of which fit the criteria defined for this study (sectors 3 to 7).

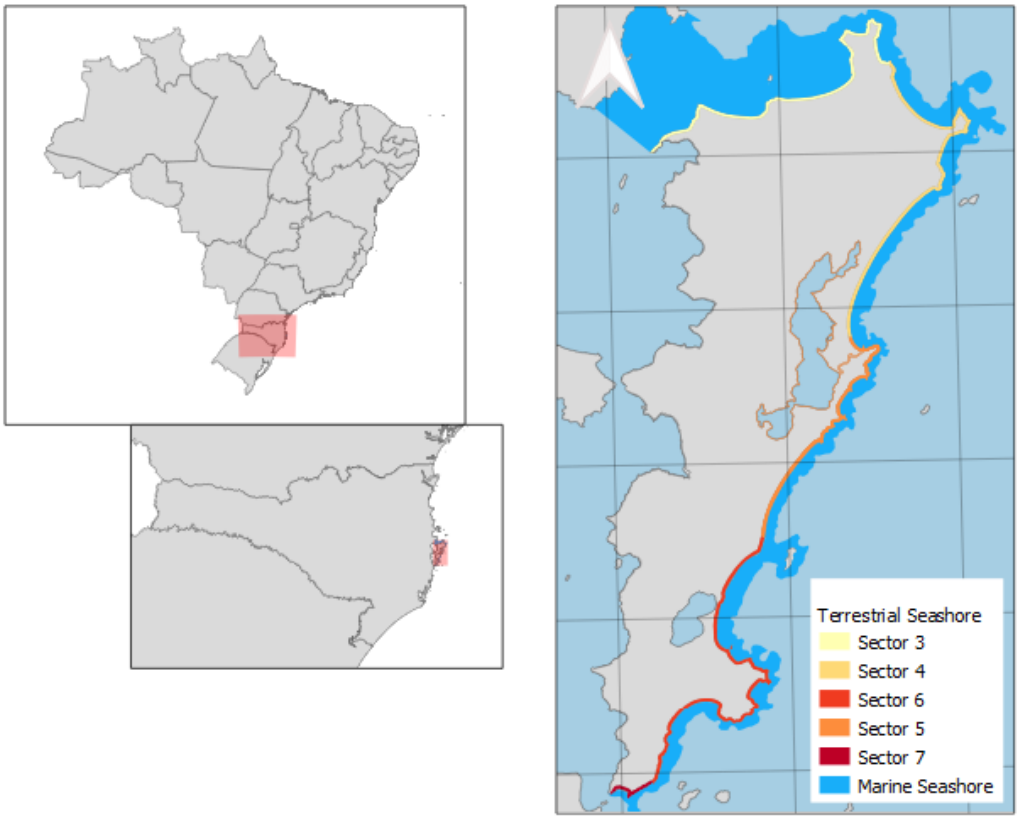

Figure 1: Seashore of Santa Catarina Island.

Sector 3 comprises the beaches of Daniela, Forte, Jurerê Internacional, Canasvieiras, Cachoeira do Bom Jesus, Ponta das Canas and Brava. Sector 4 comprises the beaches of Ingleses, Santinho, Canto das Aranhas, Moçambique, Barra da Lagoa and Lagoa da Conceição. Both sectors are characterized by having large infrastructure that caters to the island's sun and beach tourism and are also among the most populated areas. This infrastructure is only absent in Moçambique beach, where the Rio Vermelho State Park (PAERV) is delimited. Sector 5 comprises the beaches of Mole, Joaquina, Rio Tavares, Campeche and Morro das Pedras. Sector 6 includes the beaches of Armação, Matadeiro, Pântano do Sul, Lagoinha do Leste, Açores and Solidão. Both sectors 5 and 6 are less populated areas, but still have important tourist visitation, with some beaches only being accessible by trails. Finally, Sector 7 comprises only Naufragados beach, where an old fort is located.

There is no human occupation in this sector and the restricted access by trail or boat limits tourist visitation.

Shoreline boundaries in Brazil are legally defined in Federal Decree No. 5,300/2004, which regulates Federal Law No. 7,661/1988 (Law of Coastal Management in Brazil) (Brazil, 2004).

The boundaries coincide with sediment cells boundaries (Muehe, 2001), which are described in Art. 22, as

> fifty meters in urbanized areas or two hundred meters in non-urbanized areas, demarcated towards the continent from the high-water line or the final limit of the ecosystems, such as those characterized by features of beaches, dunes, escarpments, cliffs, rocky shores, restingas, mangroves, salt marshes, lagoons, estuaries, canals, where marine lands and their additions are located. (Brazil, 2004).

Based on the aforementioned legal document, the maximum limit of 200 meters was considered in this work, even in urbanized areas. This was due to the improvement in the risk analysis scale, facilitating the analysis and interpretation of results. The legal framework also indicates that in the presence of coastal lagoons, a limit of 50 meters should be added to the shoreline, which defined an increase of 50 meters around the coastal lagoon of Lagoa da Coceição.

SCI is the second most chosen location by international tourists in Brazil, leading to the development of extensive infrastructure to meet the demands of sun and beach tourism, such as resorts, hotels and gastronomic options (Ministry of Tourism, 2017). This activity is important for the municipality, since most of the income generated in Florianópolis comes from the tourism and services sectors (IBGE, 2013).

The main activities on the island were considered in order to map tourist areas, namely sun and beach tourism, and Coastal and Marine Protected Areas with public visitation, namely Parks and Environmental Protection Areas (of the acronym

in Portuguese, APAs). Therefore, mapping included sandy beaches that are often visited and Coastal and Marine Protected Areas. These areas were represented as polygons, following Lima et al. (2018), and using satellite images from Google Earth. The urbanized areas were provided by Neves et al. (2017).

At the shoreline boundaries we considered the following ecosystems: beaches, dunes, restinga (Brazilian shoreline ecosystem), rainforest, wetland and reforestation (an anthropized area with exotic species).

Ecosystem Services Matrix

The ecosystem-based matrix (Scherer and Asmus, 2016) is an instrument to support management, which is founded on the concept of Ecosystem-Based Management and ES.

The matrix considers the combination of six aspects: 1) identification of existing ecosystems, 2) services delivered by them (highlighting the main ones), 3) main ecological and socioeconomic benefits, 4) beneficiaries, 5) main pressure forces on the ecosystems, and 6) desired management responses to reduce or minimize the impacts on ES availability (Scherer and Asmus, 2016).

In the present case study, the matrix was used with a partial semantic modification and was reduced to meet the study demands. Thus, it consisted of: 1) Ecosystems, 2) ESs classified by CICES v.05 (Haines-Young and Potschin, 2018), and 3) Uses and benefits.

The classification of SCI's ESs using the CICES V.05 classification key involves a descriptor code that universally identifies the service based on five categories: section, division, group, class, service name (and descriptor code) and benefits, presenting a high level of detail when compared to other service classification methods (Haines-Young and Potschin, 2018). Such detailing leads to the possibility of defining the benefits, actors and impacts related to services in a less generalized way, which is more appropriate in the scope of coastal management.

The ESs surveyed were organized in a database of the Coastal Management Laboratory (LAGECI) at UFSC, structured through field trips and expert

opinion for its construction. The classification through CICES v.05 was also prepared by a group of experts within the scope of LAGECI.

Other aspects evaluated in the assessment also took into account field trips and the expert opinion of LAGECI members.

Risk Analysis

Risk analysis is a widely used tool to support decision making, and a means of transmitting synthesized information that supports responses to the identified threats (Lozoya; Sarda and Jimenez, 2011).

The InVEST suite of models was used to analyze risk (Sharp et al., 2016).Through its Habitat Risk Assessment model (HRA), it demonstrates the risk anthropogenic activities generate by reducing environmental quality and influencing the supply of ESs, assessing these activities' likelihood of preventing certain management goals (Sharp et al., 2016). In this study, habitats are understood as the chosen ecosystems.

The risk posed by anthropogenic threats to ecosystems is a result of the balance between exposure to a given activity and the consequences in response to such exposure, which depends not only on the impact itself, but also on the resilience of the affected ecosystem, as assumed by the HRA model (Sharp et al., 2016). Further details on how the model works can be found in Sharp et al. (2016).

To estimate exposure, the model requires information on: 1) spatial overlap between activities and ecosystems; 2) overlap time; 3) intensity; and 4) management effectiveness. Consequence is estimated considering the recovery time of the ecosystem.

The results were generated by InVEST version 3.5.0 and worked on QGIS version 3.8.1.

Coastal erosion susceptibility

Considering the relevance of extreme climate events to coastal regions, especially the southern region of Brazil, it was assumed that when areas that are susceptible to erosion also present ESs that are at greatest risk there is a priority

situation for the management of protection of these ecosystems and their services (Williams et al., 2018).

In the last decades, methodologies for assessing areas vulnerable to extreme events have been developed, and some of them are based on the assessment of physiographic descriptors that work as indicators that can infer places prone to coastal erosion, called geondicators (Bonetti et al., 2018). The susceptibility levels of areas were obtained from the occurrence of geoindicators on the shore and were classified into 5 degrees (from very low to very high), according to Bonetti et al. (2018).

The matrix input data with risk values generated by InVEST was vectored and rescheduled, so that the average between the risk and the susceptibility values could be calculated.

A 50-meter buffer was applied to the input data at susceptibility areas, in order to extrapolate their coverage area. Zonal statistics were carried out in order to cross data. The final result was a serial set of data including coastal ecosystems risk values and susceptibility values regarding coastal erosion occurrence.

A broad analysis of these results allowed ranking the priority areas for management and development of public policies. The areas at highest risk and greatest susceptibility led to the determination of the final hotspots of priority areas for managerial action.

RESULTS AND DISCUSSION

Ecosystem Services Matrix

The considered ecosystems maintai of provision services (totaling 8), maintenance and regulation services (totaling 14) and cultural services (totaling 9). These services are essential for many human uses and provide benefits such as providing water for urban supply, coastline protection and leisure and recreation (Tables 1 to 6).

Ecosystem	Section	Ecosystem Service - Code	Uses and benefits
Dune	Provision	Groundwater for domestic supply **4.2.2.1** Groundwater **4.2.2.2** Mineral resource for raw material **4.3.1.2**[1]	Supply of drinking water to the city; Health; Water supply for non-domestic uses; Landfill and civil construction works; Mining, Inputs in industrial processes, Building material for infrastructure **a**.
	Maintenance and Regulation	Reduction of visual pollution **2.1.2.3** Control of water flows **2.2.1.3** Nursery and habitat **2.2.2.3** Erosion control or prevention **2.2.1.1** Wind protection **2.2.1.4** Natural effluent processing (filtration) **5.1.1.3**	Support for tourism; Welfare; Coastal protection of infrastructure and the local community; Coastline protection; Safety; Maintenance of the sand strip; Natural self-cleaning; Bathing; Cheers; Quality of life; Shelter; Accident / disaster prevention.
	Cultural	Recreation and leisure **3.1.1.1** Visual enjoyment **3.1.1.2** Cognitive development **3.1.2.1** Environmental Education **3.1.2.2** Cultural heritage and identity **3.1.2.3** Landscape **3.1.2**.4 Spiritual experience **3.2.1.2** Inspiration for art, culture and design **3.2.1.3** Heritage **6.2.2.1**	Leisure; Support for tourism; Support for artisanal fishing; Support for educational, contemplative, artistic and sports activities; Maintenance of the cultural reproduction of the local community; Relaxation; Pleasure; Fun; Welfare; Happiness; Cheers; Job; Cultural practices that define an identity; Sense of belonging; Sense of community; Relaxation, Pleasure, Fun; Spiritual ceremonies, Spirituality; Inspiration for art, culture and design; Knowledge.

Table 1: Ecosystem Services Matrix for dunes.

1 Although it occurs at ISC, this activity is illegal. We chose to characterize it as existing in this table, although it is imperative that it be stopped in the municipality.

Ecosystem	Section	Ecosystem Service - Code	Uses and benefits
Beach	Provision	Food from wild animals 1.1.6.1	Extraction of crustaceans such as Tatuíra (*Emerita brasiliensis*), mollusks such as Cockle (*Anomalocardia brasiliana*); Work, Subsistence, Health; Fishing; Seafood; Nutrition, Tasting, Subsistence; Job.
	Maintenance and Regulation	Reduction of visual pollution 2.1.2.3 Control of water flows 2.2.1.3 Nursery and habitat 2.2.2.3 Natural effluent processing (filtration) 5.1.1.3	Comfort / Visual pleasure, Tourism, Quality of life, Transport and Navigation, Coastal protection to infrastructure and the local community; Maintenance of populations of animals and plants for human use; Natural self-purification; Bathing, Health; Fishing; Flood prevention, Waterway maintenance, Safety, Work, Fishing; Seafood; Nutrition, Tasting, Subsistence; Job.
	Cultural	Recreation and leisure 3.1.1.1 Visual enjoyment 3.1.1.2 Cognitive development 3.1.2.1 Environmental Education 3.1.2.2 Cultural heritage and identity 3.1.2.3 Landscape 3.1.2.4 Spiritual experience 3.2.1.2 Inspiration for art, culture and design 3.2.1.3 Heritage 6.2.2.1	Recreation; Tourism; Quality of life; Education; Relaxation, Pleasure, Fun, Wellness, Happiness, Health, Work; Inspiration; Relaxation; Knowledge, Satisfaction of curiosity; Cultural practices that define an identity, Sense of belonging, Sense of community, Science; Possibility of spiritual ceremonies, Spirituality; Inspiration and promotion of creativity, Subsistence.

Table 2: Ecosystem Services Matrix for beaches.

Ecosystem	Section	Ecosystem Service - Code	Uses and benefits
Wetlands	Provision	Materials from wild plants for manufacturing 1.1.5.2	Extractivism; handcrafts; Job; Subsistence.
	Maintenance and Regulation	Purification of liquid effluents 2.1.1.1 Filtration of liquid and gaseous effluents 2.1.1.2 Reduction of visual pollution 2.1.2.3 Control of water flows 2.2.1.3 Nursery and habitat 2.2.2.3 Climate regulation 2.2.6.1 Air quality 2.2.6.2 Natural effluent processing (filtration) 5.1.1.3	Self-purification in natural aquatic systems; Comfort / Visual pleasure; Maintenance of populations of animals and plants for human use; Cheers; Climatic comfort; Bathing, Human health; Air purification; Favoring living conditions on earth, Well-being
	Cultural	Aesthetic information 3.1.1.2 Cognitive development 3.1.2.1 Environmental Education 3.1.2.2 Landscape 3.1.2.4 Inspiration for art, culture and design 3.2.1.3 Heritage 6.2.2.1	Tourism; Education; Science; Recreation; Quality of life; Work, Knowledge, Satisfaction of curiosity; Inspiration and promotion of creativity; Relaxation, Pleasure, Fun, Wellness, Happiness, Health; Sense of belonging; Sense of community.

Table 3: Ecosystem Services Matrix for wetlands.

Ecosystem	Section	Ecosystem Service - Code	Uses and benefits
Reforestation	Provision	Land cultivated plants **1.1.1.1**	Extractivism; Firewood; Fuel; Heating; Wood for construction.
		Wild land plants for energy production **1.1.5.3**	
	Maintenance and Regulation	Filtering of liquid and gaseous effluents **2.1.1.2**	Visual Pleasure; Tourism, Quality of Life, Coastal Protection to infrastructure and local community; Maintenance of populations of animals and plants for human use; Natural self-depuration of air and water; Health; Sport activities; Shelter; Safety; Prevention of accidents and disasters; Favouring of living conditions on land; Wellness; Health.
		Noise reduction **2.1.2.2**	
		Visual pollution reduction **2.1.2.3**	
		Erosion control or prevention **2.2.1.1**	
		Substrate displacement control or prevention **2.2.1.2**	
		Wind Protection **2.2.1.4**	
		Nursery and Habitat **2.2.2.3**	
		Maintenance of organic matter in the soil **2.2.4.2**	
		Climate regulation **2.2.6.1**	
		Air quality **2.2.6.2**	
		Natural effluent processing (filtration) **5.1.1.3**	
	Cultural	Recreation and leisure **3.1.1.1**	Leisure; Tourism; Quality of life; Education; Relaxation, Pleasure, Fun, Well-being, Happiness, Health, Work; Inspiration, Knowledge, Satisfaction of curiosity; Science; Possibility of spiritual ceremonies, Spirituality; Inspiration and promotion of creativity, Subsistence.
		Aesthetic information **3.1.1.2**	
		Cognitive development **3.1.2.1**	
		Environmental education **3.1.2.2**	
		Landscape **3.1.2.4**	
		Spiritual Experience **3.2.1.2**	
		Inspiration for art, culture and design **3.2.1.3**	

Table 4: Ecosystem Services Matrix for reforestation.

Ecosystem	Section	Ecosystem Service - Code	Uses and benefits
Atlantic Rainforest	Provision	Materials from wild plants for manufacturing **1.1.5.2**	Hunting; Extraction; Forest Management; Heating; Dessedentation; Subsistence; Handcrafts; Firewood; Fuel; Water heating; Health.
		Wild earth plants for energy production **1.1.5.3**	
		Food from wild animals **1.1.6.1**	
		Groundwater for domestic supply **4.2.2.1**	
	Maintenance and Regulation	Liquid effluent purification **2.1.1.1**	Natural self-depuration; Water potability; Health; Air purification; Air quality; Quality of life; Visual comfort; Protection of urban infrastructure; Coast line protection; Security; Agriculture; Extractivism; Forest management; Organic fertilizer; Thermal comfort; Science; Visual enjoyment; Tourism, Maintenance of animal and plant populations for human use; Sports activities; Science; Gene maintenance. Accident prevention, Flood prevention, Shelter, Safety, Accident and disaster prevention; Forest management; Favouring living conditions on land, Well-being, Health.
		Filtration of liquid and gaseous effluents **2.1.1.2**	
		Noise reduction **2.1.2.2**	
		Visual pollution reduction **2.1.2.3**	
		Erosion control or prevention **2.2.1.1**	
		Control or prevention of substrate displacement **2.2.1.2**	
		Control of water flows **2.2.1.3**	
		Wind Protection **2.2.1.4**	
		Pollination **2.2.2.1**	
		Nursery and habitat **2.2.2.3**	
		Maintenance of organic matter in soil **2.2.4.2**	
		Climate regulation **2.2.6.1**	
		Air quality **2.2.6.2**	
		Natural effluent processing (filtration) **5.1.1.3**	
	Cultural	Recreation and leisure **3.1.1.1**	Recreation; Leisure; Tourism; Quality of life; Education; Relaxation, Pleasure, Fun, Well-being, Happiness, Health, Work; Inspiration, Knowledge, Satisfaction of curiosity; Science; Possibility of spiritual ceremonies, Spirituality; Inspiration and promotion of creativity, Subsistence; Cultural practices that define an identity; Sense of belonging; Sense of community.
		Aesthetic information **3.1.1.2**	
		Cognitive development **3.1.2.1**	
		Environmental education **3.1.2.2**	
		Cultural heritage and identity **3.1.2.3**	
		Landscape **3.1.2.4**	
		Spiritual experience **3.2.1.2**	
		Inspiration for art, culture and design **3.2.1.3**	
		Heritage **6.2.2.1**	

Table 5: Ecosystem Services Matrix for rainforest.

Ecosystem	Section	Ecosystem Service - Code	Uses and benefits
Restinga	Provision	Materials from wild plants for manufacturing **1.1.5.2** Wild earth plants for energy production **1.1.5.3** Groundwater for domestic supply **4.2.2.1** Groundwater **4.2.2.2**	Subsistence; Handcraft; Health; Health Care; Dessedentation; Quality of life; Firewood; Heating; Fuel; Water Supply; Irrigation.
	Maintenance and Regulation	Liquid effluent purification **2.1.1.1** Filtering of liquid and gaseous effluents **2.1.1.2** Noise reduction **2.1.2.2** Visual pollution reduction **2.1.2.3** Erosion control or prevention **2.2.1.1** Control or prevention of substrate displacement **2.2.1.2** Control of water flows **2.2.1.3** Wind Protection **2.2.1.4** Pollination **2.2.2.1** Nursery and habitat **2.2.2.3** Maintenance of organic matter in the soil **2.2.4.2** Climate regulation **2.2.6.1** Air quality **2.2.6.2** Natural effluent processing (filtration) **5.1.1.3**	Subsistence; Extractivism; Handcraft; Firewood; Heating Quality of life; Dessedentation; Water quality; Visual comfort; Infrastructure protection; Genetic maintenance; Thermal comfort.
	Cultural	Recreation and leisure **3.1.1.1** Aesthetic information **3.1.1.2** Cognitive development **3.1.2.1** Environmental education **3.1.2.2** Cultural heritage and identity **3.1.2.3** Landscape **3.1.2.4** Spiritual experience **3.2.1.2** Inspiration for art, culture and design **3.2.1.3** Heritage **6.2.2.1**	Leisure; Tourism; Quality of life; Education; Relaxation, Pleasure, Fun, Well-being, Happiness, Health, Work; Inspiration, Knowledge, Satisfaction of curiosity; Science; Possibility of spiritual ceremonies, Spirituality; Inspiration and promotion of creativity, Subsistence; Archeological heritage.

Table 6: Ecosystem Services Matrix for restinga.

There are 18 ESs related to dunes, 14 related to beaches, 15 related to wetlands, 27 to rainforests, 20 related to reforestation and 27 related to restinga. However, this quantification does not indicate the greater or lesser importance of each ecosystem. Dunes and beaches, for example, have fewer services, but they are essential for coastal protection.

These services benefit several stakeholders, such as the local community, artisanal and industrial fishermen, tourists, as well as some government institutions. The same ESs are threatened by 39 pressure vectors on the island, including urban development and tourism (Scherer and Asmus, 2016).

Risk assessment for ecosystems and their services

Considering the threats caused by tourism and urban areas demands for space and resources, it was possible to obtain the main areas where the island's shoreline ecosystems are the greatest risk, according to the HRA InVEST model (Figures 2 to 7).

The scenario that comes out shows the current situation, designing a baseline for comparisons with future scenarios or other locations.

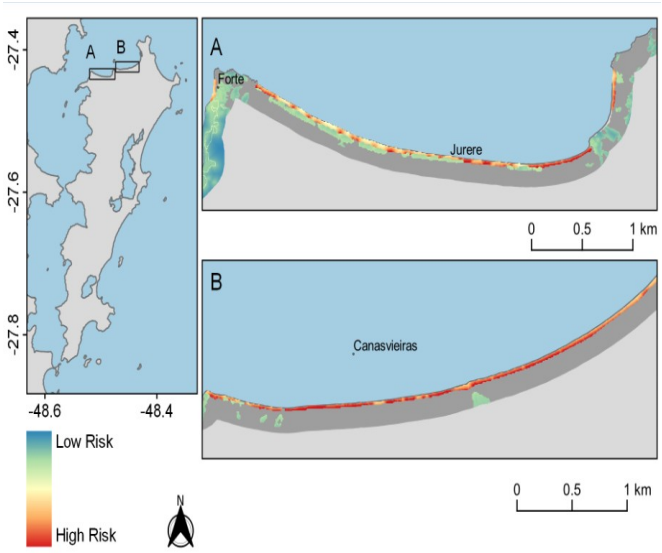

Figure 2: Ecosystem Total Risk presented by InVEST.

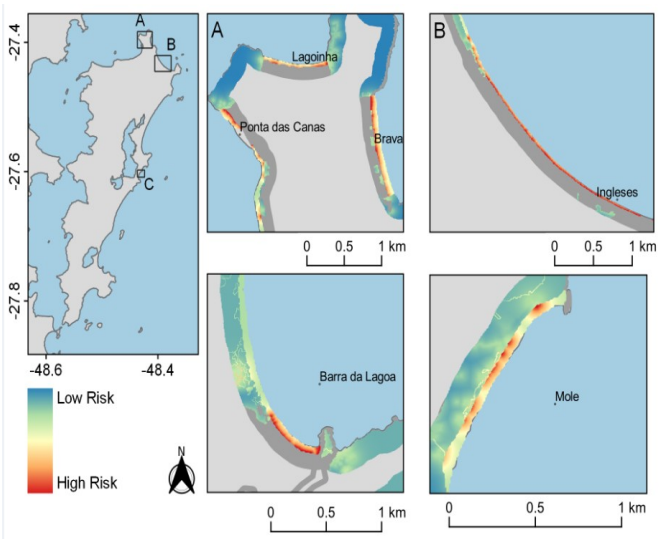

Figure 3:Total risk presented by InVEST.

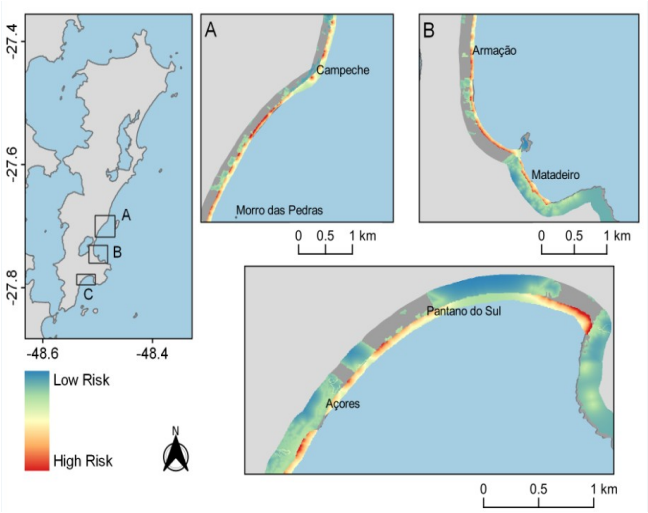

Figure 4: Total risk presented by InVEST.

The results point out areas at very high risk in all sectors except for sector 7, at the south side of the island (Figure 1). This same sector comprises a region without access arrangements or other infrastructure. The access to the beach named Naufragados is only by trail, leading to a low incidence of public visitation compared to beaches that are easily accessed by streets and roads.

As expected, the regions characterized by the presence of urban infrastructure such as housing, roads and services for the population, which are also areas that are intended for tourist activities, presented areas at greater risk. The

shorelines of the beaches of Jurerê, Canasvieiras, Cachoeira do Bom Jesus, Lagoinha, Ponta das Canas, Brava, Barra da Lagoa, Mole, Campeche, Morro das Pedras, Armação, Pântano do Sul and Açores present both these conditions. Also, as shown in Figures 2, 3 and 4, they are areas in which ecosystems and their services are at greatest risk.

As already explained, the InVEST HRA model considers in its calculation of the total risk not only the threats, but also the intrinsic characteristics of the ecosystems, as well as the number of existing ecosystems in each pixel analyzed. This way, the type and amount of ecosystems present in each pixel can also impact total risk.

The areas at very high risk are, therefore, those that combine the existence of urban infrastructure, tourism and the association of fragile ecosystems.

The results generated for each ecosystem allow better interpretation of the total risk results.

Dune risk

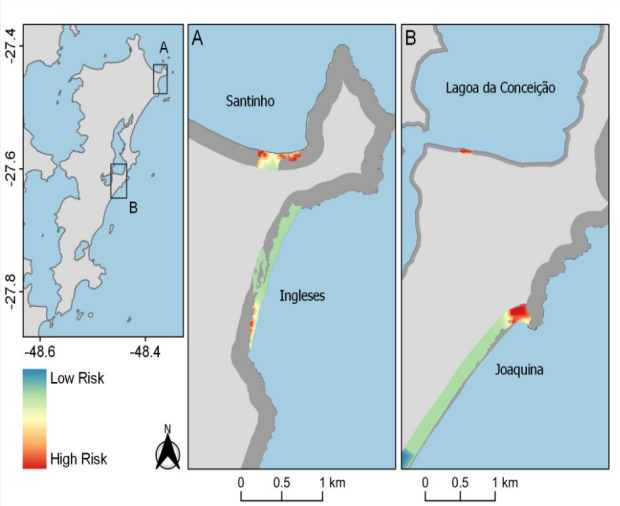

Figure 5: Dune cummulative risk.

According to the model, the sand dunes fields are at very high risk at four spots, especially at Praia dos Ingleses and Joaquina. In ISC, dune formations are

quite common, and in the study area they are concentrated in sectors 4, 5 and, to a lesser extent, in sector 6 (Figure 6).

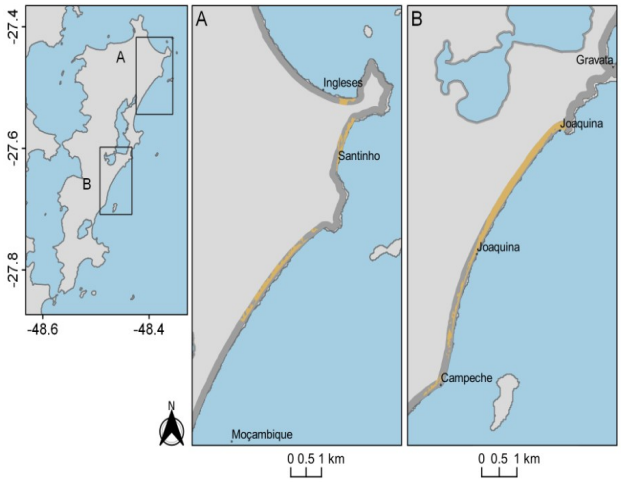

Figure 6: Parcial dune cover in SCI.

The shorelines of southern Joaquina beach and Moçambique beach are located where there is the highest incidence of dunes (Figure 6). Both beaches having a shore that conserves their natural ecosystems, with little infrastructure, and virtually no housing.

Beach risk

The scenario generated for the beaches points out a greater number of areas at very high risk throughout all sectors of ISC shoreline. However, there is a greater concentration of very high-risk areas in the northern part of the island (sector 3, Figure 7), also presenting high-risk areas on the east side (sector 5, Figure 8) and in the south side (sector 6, Figure 8).

This fragile and dynamic ecosystem provides the enjoyment of tourist activities and has been pressured by the advance of urban infrastructure. At the same time, the advancing sea level causes coastal squeeze, which leads to the loss of the ecosystem (Schlacher et al., 2008).

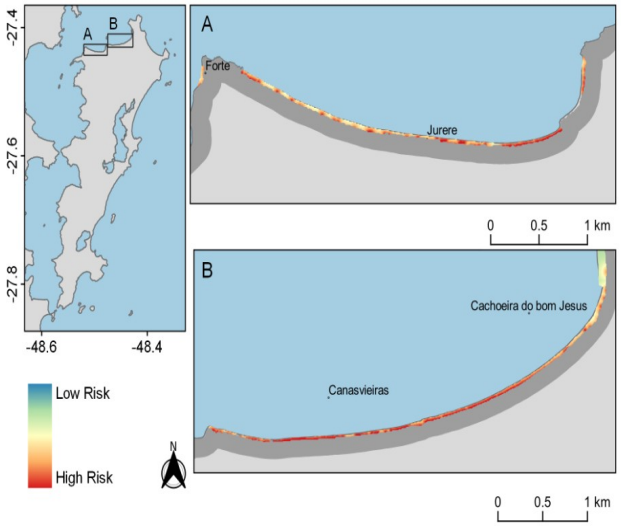

Figure 7: Beach total risk (a)

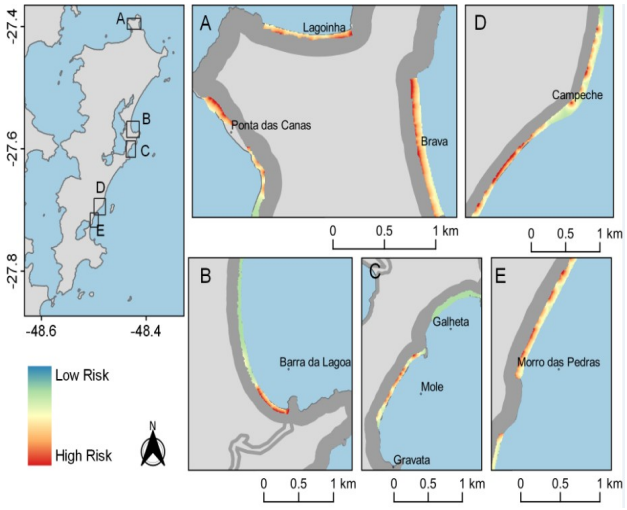

Figure 8: Beach total risk (b)

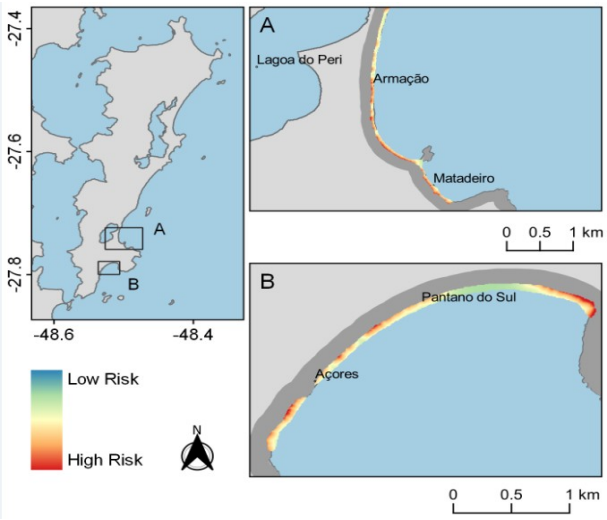

Figure 9: Beach total risk (c).

Among the 11 threatened beaches there are Canasvieiras, Cachoeira do Bom Jesus, Ponta das Canas, Lagoinha do Norte, Brava, Ingleses, Barra da Lagoa, Campeche, Armação, Matadeiro and Pântano do Sul. All of them, except for Matadeiro beach, are characterized by urban occupation and tourist visitation that influence the high risk. Although the Matadeiro beach has no infrastructure, its proximity to Armação beach and consequent tourist use possibly influenced the high risk found in this location.

It is important to note that sun and beach tourism is one of the Island's economic bases (Ministry of Tourism in Brazil 2010), essentially dependent on the cultural ecosystem services delivered by beaches (Table 2).

A high number of beaches with a high risk of loss or modification of these ecosystems and their services are perceived. In a context of land speculation, intense tourism and extreme events affecting the size of the sand strip, this ecosystem, which has few legal instruments for protection in Brazil (Souza, 2009), should be a priority for management.

Reforestation risk

The reforested areas are mostly located on the shore of Moçambique beach (Figure 10, A) with no consolidated human occupation. The risk scenario that was generated showed a few areas at very high risk (Figure 10).

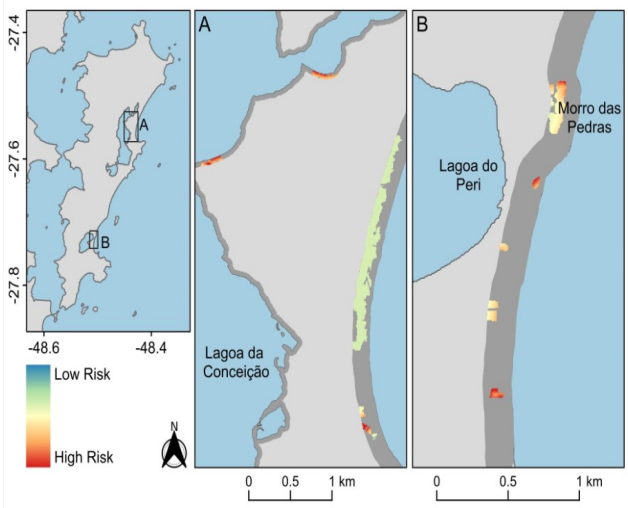

Figure 10: Reforestation total risk.

The risk scenario generated could be due to the fact that this ecosystem is not fragile and is not affected by urbanization. This ecosystem is located in an area originally occupied by sandbanks and dunes, which were converted into agricultural fields for planting exotic species in the 1970s (Caruso, 1990). After about 40 years, the exotic vegetation interposed with the secondary vegetation, predominating exotic species such as pine (*Pinus* sp.) and eucalyptus (*Eucalyptus* sp.) (Ferreti, 2013).

Although there is no native vegetation, the ecosystem is in a protected area (PAERV), which protects it from suppression for urbanization.

Rainforest risk

For the rainforest, the model pointed out three critical areas in Morro das Pedras, Matadeiro and Lagoa da Conceição. The high values correspond to the north (sector 3), the east (sector 5), and the south (sector 6) (Figure 11).

The risk was classified as low or very low in most of the shoreline. The largest forest remnant areas are associated with rocky shores and hills, where access is difficult and ecosystems are protected by law (Brazil, 2012). Generally, these areas have fewer urbanized areas and tourist activities are not so intense as sun and beach tourism, due to trail access restrictions.

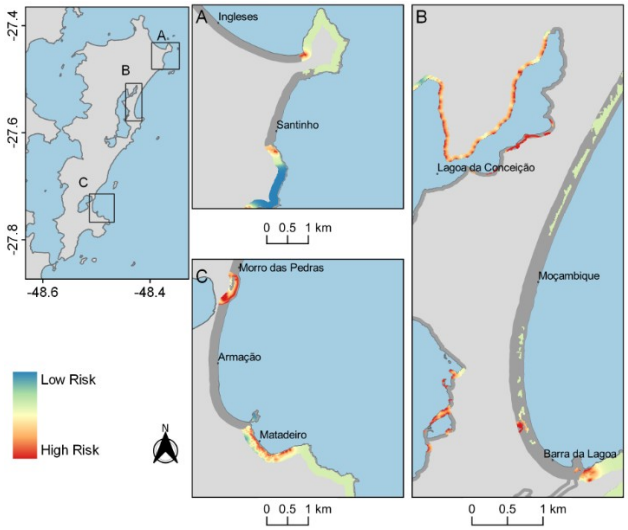

Figure 11: Rainforest total risk.

Restinga risk

Adjacent to the rainforest, restinga points out a very high risk in the northern, eastern and southern parts (sectors 3, 4, 5 and 6) (Figure 12 and 13), highlighting seven stretches of shoreline at the beaches of Forte, Jurerê, Brava, Ingleses, Santinho, Campeche and Armação, in addition to Lagoa da Conceição (Figures 12 and 13).

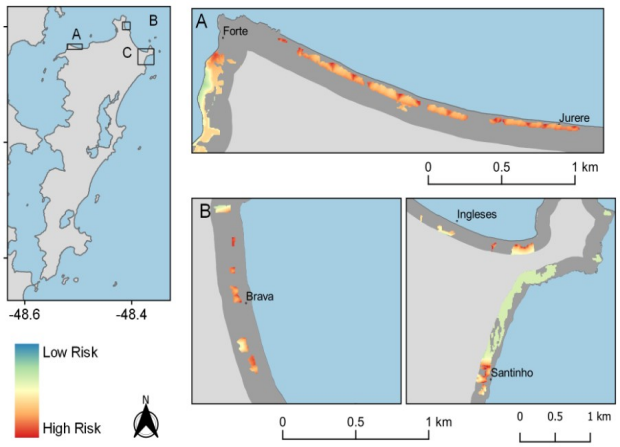

Figure 12: Restinga total risk at the north shore.

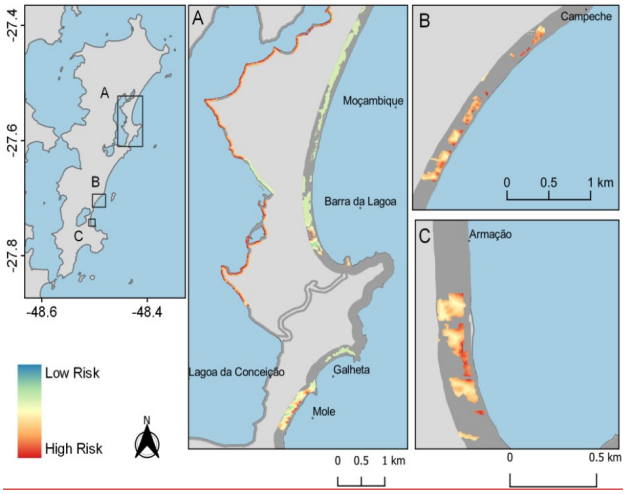

Figure 13: Restinga total risk at the east shore.

Along with the beaches, restinga was one of the ecosystems that had the greatest occurrence of formations at high and very high risk. This fragile

ecosystem is also affected by coastal squeeze, suffering from urbanization and rising sea levels. At the same time, it is where the intense sun and beach tourism occurs.

In view of the concentration of areas under high and very high risk, they should be a priority in management and protection.

Wetland risk

The wetland, the less expressive ecosystem in this study area, presented the smallest area at very high risk. This ecosystem is generally far from urbanized areas and is not widely used for tourism. The only very high-risk area was located in sector 5, surrounding parts of Lagoa da Conceição, overlapping with the Rio Vermelho State Park (PAERV), but near the road.

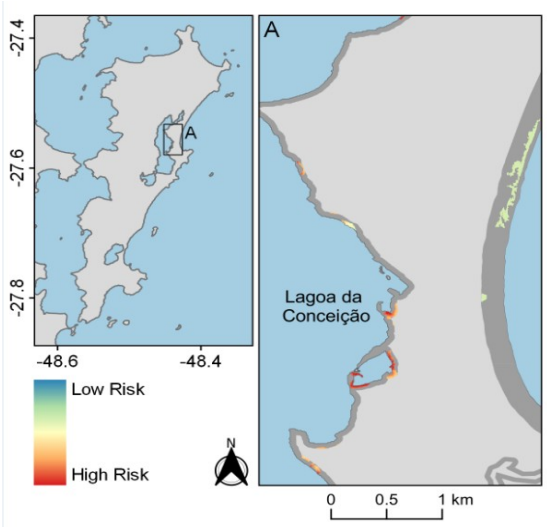

Figure 14: Wetlands risk area.

Habitat Risk Assessment

The threat to the ecosystems biophysical structure leads to the modification or loss of ecological functions that are responsible for the existence of ecosystem services (Haines-Young et al., 2016). Thus, when we have an indication of risk from high to very high, it is understood that these places are suffering such pressure that ecosystems are highly likely to lose part or all ecosystem services (Halpern et al., 2008).

The model provided by the InVEST Habitat Risk Assessment brought results that allow a diagnosis of the current situation in ISC, indicating priority areas for immediate management response regarding the protection of ecosystems and their services.

Assuming that the ISC shoreline ecosystems are fundamental for the well-being of the island residents and visitors, as well as for the economic activities of Santa Catarina state capital, the generated risk maps can support coastal management in protecting endangered ecosystems.

In the case of the Island of Santa Catarina, these actions should be directed towards the restinga, beaches and rainforest ecosystems, which presented a greater amount of area at high and very high risk.

Risk and erosion hotspots in coastal ecosystems in the Island of Santa Catarina

The risk results that were generated by InVEST HRA model, in association with the erosive events susceptibility that was generated by geoindicators (Bonetti et al., 2018), pointed out 14 areas at very high risk of losing their ESs, distributed over seven beaches (Figure 15).

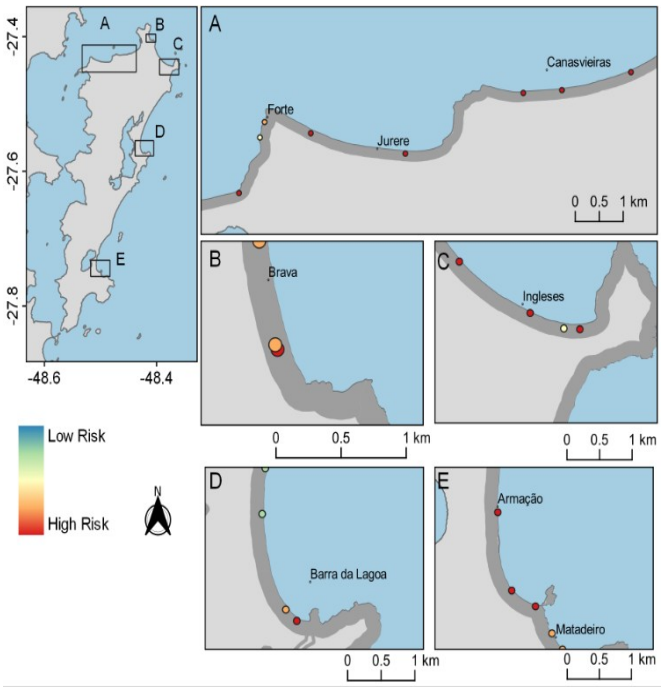

Figure 15: Ranking areas for management intervention.

The association between ecosystem risks and coastal erosion susceptibility indicates the areas where there is a possibility of ecosystem loss due to urbanization and tourist activities, as well as coastal erosion, therefore indicating a priority for management actions.

On the northern side of the Island (sector 3), seven points were classified with a very high degree of association between risk and susceptibility. These points are located at five classic beaches for tourist activities: Daniela, Jurerê, Canasvieiras, Cachoeira do Bom Jesus and Brava. In these beaches there is a need for immediate intervention, in order to organize the uses and activities, safeguarding the ecosystems and, consequently, the local population by the effects of erosion events.

At the same way, also in the northern region (sector 4 - Praia dos Ingleses), three other hotspots associating risk and susceptibility were pointed out. With beach, dune and restinga ecosystems at risk.

At sector 5, hotspots that require immediate intervention are located in the Barra da Lagoa shoreline. The ecosystems associated with the threatened area are the rainforest and beach. On other hand, in sector 6, the results point out three hotspots on the Armação shoreline, where restinga, beach and wetland ecosystems are at risk.

Risk, susceptibility and Ecosystem Services

Beaches and restingas at risk can potentially be affected in the maintenance or even loss of ESs. Among the 30 ecosystem services associated with restinga, the formation of groundwater for domestic supply is among the most relevant (Cices code 4.2.2.1) bringing quality of life, irrigation and water supply in the ISC urban area. Other important ESs are purification of liquid effluents (Cices code 2.1.1.1), climate regulation (Cices code 2.2.6.1), pollination (Cices code 2.2.2.1), environmental education (Cices code 3.1.2.2), reduction of visual pollution (Cices code 2.1.2.3), recreation and leisure (Cices code 3.1.1.1).

Regarding ESs related just to beaches, the service of water flow control (Cices code 2.2.1.3), which allows navigation and coastal protection to infrastructure and the local community, is also at risk, impacting the resident population, the tourists and the beach tourism trade. According to the model, a total of 19 ESs delivered by beaches are at high and very high risk.

In compliance to the ESs Matrix (Table 2), the threat to beaches and services like landscape (Cices code 3.1.2.4) and visual pleasure (Cices code 3.1.2.2) put at risk the natural resources that foster tourism, as there might be changes in the landscape, which can affect tourist preferences.

Beaches and restingas are also related to coastal protection services, and are threatened in areas with erosion susceptibility, which may justify the hotspots. These services should be emphasized, especially considering that 7.4% of coastal erosion damage in the state of Santa Catarina occurred on the east coast of ISC over the last 20 years (Krueger, 2011). In 2010, the island's shoreline was drastically affected by extreme events when 74 houses and 1,803 people were impacted, 21 of which were displaced (Krueger, 2011).

This event affected the Barra da Lagoa and Armação beaches, leading the municipal government to declare an emergency situation. The forecast for the next 50 years regarding coastline movement and flood showed catastrophic flooding results for practically the entire neighborhood at Barra da Lagoa (Klein et al., 2016).

The threat to sand dunes is also a threat to a set of services related to coastal protection. Infrastructure and urban constructions, for example, affect the ES of erosion control or prevention (Cices code 2.2.1.1), which provides the benefits of protecting infrastructure and the local community, as well as the coastline, offering security, maintenance of the sand strip, shelter, accident/disaster prevention and support for tourism (Souza, 2009).

The work of Lozoya, Sarda and Jimenez (2011) points out that human uses, coastal erosion and floods are the greatest threats to ESs in S'Abanell beach, in Spain. Among the most threatened ESs are: “spiritual & historic”, “habitat”, “recreation & aesthetic”, “water supply” and “disturbance regulation”, classified by a methodology other than CICES.

Roig-Munar et al. (2012) analyzed four dune-beach systems in the Balearic Islands, also in Spain, where they verified that the places where erosive events occur are those where there are more human uses and occupation. The study indicates management actions towards the maintenance of ecosystems and to reduce erosion risk (Roig-Munar et al., 2012).

Among the 32 services offered by the rainforest, control and prevention of substrate transportation (2.2.1.2) provides security and prevents accidents and disasters for the urban infrastructure and the population. Nursery and habitat (2.2.2.3) is another endangered service that provides shelter, genetic maintenance and also maintenance of animal and plant populations for human use, for example. In the northern perimeter of the Lagoa da Conceição, in sector 5, this service is especially important since the area is part of Rio Vermelho State Park, where animal populations take refuge.

From the 15 ESs associated with wetland, the effluent natural treatment (filtration) (5.1.1.3) contributes to self-purification in the aquatic system, improving the water bodies.

The loss of these ESs leads to a loss in public and private properties and goods along the coastline, as well as in the real estate value of coastal dwellings and the beach's landscape value. It also leads to the impairment of the region's tourist potential and losses in local socioeconomic activities (Souza, 2009), requiring management intervention measures on the shoreline to safeguard ecosystems and consequently protect the effects of coastal erosion.

Conclusion

One of the challenges of shoreline management is to reconcile the increase in tourism and economic demand with ecological conservation, with the maintenance of sediment transport dynamics (Schlacher et al., 2008) and ecosystem services.

Worldwide experiences in shoreline management point out that planning based on Shoreline Management Plans is highly recommended for an effective management of the shore (Williams and Micallef, 2009; Noujas and Thomas, 2018).

In these plans, it is common to establish setbacks area setting an area adjacent to the beach with a variable length that should not be occupied in order to keep its permeability, maintaining or restoring local ecosystems (Souza, 2009).

These areas are the prerogative of most of the beach or shoreline management. The basis is to maintain or restore ecosystems, thus ensuring all services they provide, highlighting those that concern coastal protection and its benefits. An example could be seen at Moçambique beach as it has a setback imposed by the restrictions of the State Park, safeguarding the ecosystems, which the HRA InVEST model pointed out as low risk (Figure 3C).

The results of this study could contribute to shoreline management and could also be included in the Brazilian Shoreline Integrated Management Plan (of the acronym in Portuguese, PGI). The identification of risk areas is the first step to prioritize management initiatives.

For instance, sectors 3 and 4 of the shoreline on the Island of Santa Catarina (figure 1) present a greater demand for immediate intervention due to the

very high risk of changes in the structure and functions of ecosystems and hence in the availability of ES. Intense occupation, tourism, fragments of remaining ecosystems as well as the high susceptibility to erosive events, determine a very high risk.

There are two other regions in sectors 4 and 6 that, despite having a smaller number of hotspots, call for attention especially because they have been the target of extreme events.

The risk that these places to change or lose their ESs is also a risk for some of the local activities, especially tourism, which economically is very important for the region (Ministry Of Tourism In Brazil, 2010; Souza, 2009), also requiring an immediate response.

Although there are limitations in the models that integrate ESs (Sharp et al., 2016), they are important for planning, especially when both social participation and communication of accessible information to the general public are necessary (Guerry et al., 2012).

Considering ESs and the benefits to human welfare in the context of management brings to light the importance of maintaining ecosystems in urban planning. The ESs Matrix is an important and significant analysis tool for scientific research and also for supporting management. The Matrix reduces the associated uncertainties and helps in establishing more effective public policies, as it clarifies the consequences of each decision making (Scherer and Asmus, 2016). It pointed out what benefits will be affected in the absence of a certain ecosystem (Asmus et al., 2018; Scherer and Asmus, 2016).

The matrix can be adapted to various situations, as in this study, when some columns were excluded to suit the purpose of the results. Thus, the Ecosystem Services Matrix could be considered in the development of Shoreline Management Plans.

If Shoreline Management Plans are the option for shoreline planning, it is important that they are supported by methodologies that work with threats, risks and susceptibility. In this way, it is possible to determine objectives and targets based on evidence, so that the desired future scenario can be achieved.

3 CONSIDERAÇÕES FINAIS

O presente trabalho obteve, através da modelagem do risco aos ecossistemas e seus serviços, considerando ameaças antrópicas, um panorama do grau de risco existente nas praias arenosas expostas e ecossistemas adjacentes, na Ilha de Santa Catarina.

Ao assumir a susceptibilidade à erosão como fator a ser considerado na hierarquização de áreas prioritárias para a gestão, foi possível obter um cenário que indica a necessidade de ações de intervenção imediata em três pontos principais norte da ilha, Barra da Lagoa e Armação. As áreas em que os ecossistemas e seus serviços necessitam maior intervenção para manutenção, são as mesmas que sustentam grande parte das atividades turísticas na ilha as quais apenas se consolidam com a manutenção dos Serviços Ecossistêmicos, sendo necessárias políticas públicas imediatas para o resguardo dos ecossistemas, das atividades econômicas e do bem-estar social.

Confrontando os ecossistemas, seus serviços, benefícios e atores, com a legislação que dá suporte à gestão, é possível fazer uma análise científica do panorama atual, bem como fornecer à gestão um instrumento base para a tomada de decisão com a possibilidade do desenvolvimento de cenários de escolha.

A manutenção dos SE implica necessariamente a conservação e recuperação dos ecossistemas, o que tem início em metas e ações que envolvam o zoneamento da orla e seu planejamento através dos instrumentos disponíveis no Brasil: Plano Municipal de Gerenciamento Costeiro (PMGC) e Plano de Gestão Integrada (PGI).

O estabelecimento de *setbacks* nas áreas que apresentaram grau muito alto na média entre risco e susceptibilidade, em um zoneamento garantido pelos instrumentos de planejamento supramencionados, pode vir a modificar o cenário atual, evitando a perda dos serviços e fazendo uso dos instrumentos de planejamento disponíveis para uma gestão fundamentada.

O planejamento de ações com base ecossistêmica é um passo fundamental para a gestão efetiva da orla marítima: integrando setores, ambientes e áreas do conhecimento, assumindo planos de ação e monitoramento com base no

conhecimento científico e na análise de risco, e ancorado na participação social por meio da governança prevista na base legal.

REFERÊNCIA BIBLIOGRÁFICA

1 AGARDY, T.; DAVIS, J.; SHERWOOD, K. VESTERGAARD, O.(2011). **Taking Steps toward Marine and Coastal Ecosystem-Based Management - An Introductory Guide** . United Nations Environment Programme. Nairobi, Kenya.

2 ARKEMA, K. K., VERUTES, G.M., BERNHARDT, J.R. et al. (2014). Assessing habitat risk from human activities to inform coastal and marine spatial planning: A demonstration in Belize. **Environmental Research Letters**, v. 9, n. 11.

3 ASMUS, M.L., NICOLODI, J. , SCHERER, M.E.G. (2018). Simple to be Useful: Ecosystem Base for Coastal Management. **Journal of Environment & Development**., v. 44, p. 4-19.

4 BARRAGÁN, J. M.; ANDRÉS, M. DE. (2016). Fundamental aspects for an integrated management of the coastal areas of Spain: concepts, terminology, context and delimitation criteria. **Journal of Integrated Coastal Zone Management,** v. 16, n. 2, p. 171–183.

5 BÖHNKE-HENRICHS, A., BAULCOMB, C. KOSS, R., SALMAN HUSSAIN , S. AND de GROOT, R.S. (2013). Typology and indicators of ecosystem services for marine spatial planning and management.. **Journal of Environmental Management** 130; 135-145.

6 BONETTI, J., RUDORFF, F.M. CAMPOS, A.V. and SERAFIM, M.B. (2018). Geoindicator-based assessment of Santa Catarina (Brazil) sandy beaches susceptibility to erosion. **Ocean and Coastal Management**, v. 156, p. 198–208.

7 BRAZIL (1988). **Federal Law nº 7661.** Establishes the National Coastal Management Plan and makes other arrangements. Official Gazette, 1ª serie - nº 116, n. Pdr 2020, p. 3901–3902

8 BRAZIL (2004). **Federal Decrete nº 5.300.** Regulates Law 7.661, of May 16, 1988, which institutes the National Coastal Management Plan - PNGC,

establishes rules for the use and occupation of the coastal zone, establishes criteria for the management of the seashore, and makes other provisions.

9 BRAZIL (2012). **Federal Law nº 12651. P**rovides for the protection of native vegetation.

10 BRAZIL (2015). **Federal Law n° 13.240**. Provides for the administration, disposal, transfer of management of Union property and its use for the constitution of funds.

11 BRAZILIAN GEOGRAPHY AND STATISTICS INSTITUTE (IBGE). (2013). **Demographic Census 2010.** Methodology of the Demographic Census 2010. Rio de Janeiro: IBGE (Series Metodological Reports, v. 41).

12 CARUSO, M. L. (1990)**. O desmatamento da Ilha de Santa Catarina de 1500 aos dias atuais.** UFSC, Florianópolis, Brazil.

13 CHAN, K. M. A.; RUCKELSHAUS, M. C. (2010). Characterizing changes in marine ecosystem services. **Biology Reports**, 2:54.

14 CHARLES W. FINKL (ORG.). (2013). **Coastal Hazards.** Springer Science+Business Media Dordrecht.

15 COASTAL ZONE MANAGEMENT AUTHORITY AND INSTITUTE (CZMAI). 2016. **Belize Integrated Coastal Zone Management Plan**. CZMAO, Belize City.

16 DIEGUES, A.C.S. (2011). **Ecologia Humana e Planejamento em Áreas Costeiras**. Ed. USP, São Paulo, Brazil.

17 FERRETI, O.E. (2013). **The Nature Protected Areas on the Santa Catarina Island,** Brazil. Dissertation.UFSC, 346p.

18 GRUBER, N.; BARBOZA, E.; NICOLODI, J. (2003). Geography of coastal and oceanographic systems: subsidies for integrated coastal zone management. **Gravel**, n. 1, p. 81–89.

19 GRUMBINE, R.E. What is ecosystem management? **Conservation Biology,** v.8:27–38.

20 GUERRY, A. D., RUCKELSHAUS, M.H., ARKEMA, K.K. et al. (2012). Modeling benefits from nature : using ecosystem services to inform coastal and marine spatial planning. Journal of Biodiversity Science, **Ecosystem Services & Management,** 8:1-2, 107-121.

21 GUERRY, A. D. (2018). Icarus and Daedalus: Conceptual and Tactical Lessons for Marine Ecosystem-Based Management. **Frontiers in Ecology and the Environment,** v. 3, n. 4, p. 202–211.

22 HAINES-YOUNG, R., POTSCHIN, M.B., CZÚCZ, B. (2016). **Report on the use of CICES to identify and characterise the biophysical, social and monetary dimensions of ES assessments**. EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007. Available from: http://www.esmeralda-project.eu/documents/1/.

23 HAINES-YOUNG, R. and POTSCHIN, M. B. (2018). **Common International Classification of Ecosystem Services (CICES) V5. Guidance on the Application of the Revised Structure.** January, p. 32.

24 HALPERN, B.S., McLEOD, K.L., ROSENBERG, A.A., CROWDER, L.B. (2008). Managing for cumulative impacts in ecosystem-based management through ocean zoning. **Ocean & Coastal Management** 51. 203-211.

25 KLEIN, A. F. , PRADO, M.F.V., DALINGHAUS C., CAMARGO, J.M. (orgs.) (2016). **Methodology for quantification of coastal hazards and projection of future coastlines as a subsidy for adaptation studies of coastal zones: northern coast of Santa Catarina Island and surroundings.** Ministry of Envrionment in Brazil, Brasília, Brazil.

26 KRUEGER J. (2011). **Analysis of meteorological and oceanographic parameters of extreme events, which occurred between 2001 and 2010, in the State of Santa Catarina.** Dissertation. University of Vale do Itajaí, 77p.

27 LESLIE, H. M & MCLEOD, K. L. (2007). Confronting the challenges of implementing marine ecosystem-based management. **Frontiers in Ecology and the Environment,** v. 5(10): 540–5482007.

28 LIMA, A. DE S., FIGUEIROA, A.C., GANDRA, T.B.R. et al. (2018). Ecosystem-based information as a tool to support integrated coastal management on the Island of Santa Catarina, Brazil. **Journal of Environment & Development.,** v. 44, p. 20–35.

29 LONG, R. D.; CHARLES, A.; STEPHENSON, R. L. (2015). Key principles of marine ecosystem-based management. **Marine Policy**, v. 57, p. 53–60.

30 LOZOYA, J. P.; SARDA, R.; JIMENEZ, J. A. (2011). A methodological framework for multi-hazard risk assessment in beaches. **Environmental Science and Policy,** v. 14, n. 6, p. 685–696.

31 MARTÍNEZ, M. L. , INTRALAWAN, A.,VÁZSQUEZ, G., PÉREZ-MAQUEO, O., SUTTON, P. and LANDGRAVE, R. (2007). The coasts of our world: Ecological, economic and social importance. **Ecological Economics,** v. 63, n. 2–3, p. 254–272.

32 MINISTRY OF TOURISM IN BRAZIL. (2010). **Sun and beach tourism: Basic Orientations.** Brasília, Brazil.

33 MORI, N., YASUDA, T., MASE, H., TOM, T. and OKU, Y. (2010). Projection of Extreme Wave Climate Change under Global Warming. **Hydrological Research Letters**, v. 4, n. 0, p. 15–19.

34 MUEHE, D.(2001). Morphodynamic Criteria for Establishing Coastal Rim Boundaries for Management Purposes. **Brazilian Journal of Geomorphology**, v. 2, n. 1.

35 NEVES, J., ORNON, A., VOIRON-CANICIO, C., HORN FILHO, N. O. (2017). Land use and land cover mapping of Santa Catarina Island, Brazil, based on high spatial resolution imaging. **Geosu**l, v.32, n.65.

36 NOUJAS, V. and THOMAS, K. V. (2018). Shoreline management plan for a medium energy coast along west coast of India. **Journal of Coastal Conservation.**v.22, p.695–707.

37 OLIVEIRA, M. R. L. DE and NICOLODI, J. L. (2012). Coastal Management in Brazil and the ten years of the Orla Project. An analysis from the perspective of

public administration. **Journal of Integrated Coastal Management ,** v. 12, n. 1, p. 89–98.

38 PORTZ, L., Rockett , G.C.; Franchini, R.A.L.; Manzolli, R.P. and GRUBER, N.L.S. (2014). Coastal dune management: the use of geographic information system (GIS) in thedevelopment of management plans in the coast of Rio Grande do Sul, Brazil. **Journal of Integrated Coastal Zone Management.** 14(3):517-534 .

39 RIBEIRO, M.C., METZGER, J.P., MARTENSEN, A.C., PONZONI, F.J., HIROTA, M.M. (2009). The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. **Biological Conservation**, v.142:1141-1153.

40 ROIG-MUNAR, F. X., MARTIN-PRIETO, J.A., RODRIGUEZ PEREA, A.; PONS G.X., GELABERT,B. and MIR-GUAL,M. (2012). Risk Assessment of Beach-Dune System Erosion: Beach Management Impacts on the Balearic Islands. **Journal Of Coastal Researc**h, v. 28, n. 6, p. 1488–1499.

41 RUBERTI, D., VIGLIOTTI, M., i MAURO, A., CHIEFFI, R. and Di NATALE, M. Human influence over 150 years of coastal evolution in the Volturno delta system (southern Italy). **Journal of Coastal Conservation,** 1-21.

42 SARDÁ, R., VALLS, J.F., PINTÓ, J, ARIZA, E. et al. (2015). Towards a new Integrated Beach Management System: The Ecosystem-Based Management System for Beaches. **Ocean & Coastal Management** XXX,1-11.

43 SCHERER, M.; ASMUS, M.; SANCHES, M.; POLETI, A. E. (2011). **Coastal management in Brazil: analysis of the situation and proposals for potential enhancement**, in Farinós, J. (ed.), Integrated Coastal Zone Management. More than just revised coastal management?, v.9. Valência, Spain, IIDL/Publications of Valencia´s University, p. 161–173.

44 SCHERER, M. and ASMUS, M. (2016). Ecosystem-Based Knowledge and Management as a tool for Integrated Coastal and Ocean Management: A Brazilian Initiative. **Journal of Coastal Research**, v. 75, n. 1, 75, p. 690–694.

45 SCHLACHER T.A., D.S. SCHOEMAN, J.E. DUGAN, M. LASTRA, A. JONES, F. SCAPINI, AND A. MCLACHLAN (2008). Sandy beach ecosystems: key features, management challenges, climate change impacts, and sampling issues. **Marine Ecology** 29: 70-90.

46 SHARP, E. R., TALLIS,H.T., RICKETTS, T. et al. (2016). **InVEST +VERSION+ User's Guide.** The Natural Capital Project, Stanford University, University of Minnesota, The Nature Conservancy, and World Wildlife Fund. Available in: <http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/InVEST_+VERSION+_Documentation.pdf>

47 SOUZA, C.R. (2009). Coastal Erosion and the Challenges of Coastal Management in Brazil. **Journal of Integrated Coastal Management**, v. 9, n. 1, p. 17–37.

48 STELZENMÜLLER, V., COLL, M., MAZARIS, A.D. et al. (2018). A risk-based approach to cumulative effect assessments for marine management. **Science of the Total Environment,** v. 612, p. 1132–1140.

49 WILLIAMS, A. and MICALLEF, A. (2009). **Beach Management: Principles and Practice**. Routledge, New York.

50 WILLIAMS, A. T., RANGEL-BUITRAGO, N., PRANZINI, E., ANFUSO, G. (2018). The management of coastal erosion. **Ocean and Coastal Management**, v. 156, p. 4–20.