

IMPACTS ON THE DUNES SYSTEM: NATURAL DYNAMIC VERSUS ANTHROPOGENIC INTERFERENCE

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Introduction

Coastal zones are, currently, the spaces under the highest environmental pressure, which makes them particularly vulnerable, since they provide shelter to rare and fragile environments. They are also the target of an increasing urbanization and concentration of human activities. More and more, the cultural valorization of these spaces has been an important vector of occupation and accelerated urbanization.

The fragile and dynamic coastal environments have been intensely used for recreation, leisure activities and tourism purposes. In the last five decades, for instance, the northern coast of Rio Grande do Sul has experienced an accelerated impulse of the implementation of lots for second residences. On these terms, the real estate market designates the areas with lower landscape and scenic values for the middle class stratas, and the most valuable spaces with more beautiful landscapes, for hotels, condominiums, and luxury housing developments, with the latter often being located on the most vulnerable sectors of the coastal environments (STROHAECKER, 2007).

This intense urbanization, conditioned by the valorization of coastal areas, has compromised the landscaping and environmental quality of several of their typical environments. In this context, an exact diagnosis of the environmental conditions in these spaces is imperative, so that the public organizations are properly subsidized for the elaboration of social-environmental management and land use plans. Then it will be possible to aim for sustainable development of the coastal areas.

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Capão da Canoa municipality, on the northern coast of Rio Grande do Sul, is one of the most popular destinations during summer, and therefore, characterized by second-residence houses. The municipality has experienced a vertiginous urban and demographic increase (only the resident population is considered for the demographic rate increase), reaching an annual average value of 5.16% between the years of 1991 and 2000 (SEPLAG, 2010). The disorderly occupation of the shoreline is responsible for the vulnerability index increase of its natural systems, such as the foredunes, and geomorphological features that are characteristic of the coastal state's landscape. The latter are also important considering the protection of urban settlements against undertows, which can cause huge material losses. Monitoring the dunes state is an important element of the dune management programs, especially on a scenario of severe storms due to climate change (ANTHONY et al, 2007). Establishing which shoreline's sectors are more vulnerable to erosion, by natural dynamic processes as well as by the influence of the associated anthropogenic interference, becomes an interesting method for coastal zone management, urban planning, and government decision making.

Therefore, this work aims at analyzing the seasonal variability of the impacts on the foredunes system of Capão da Canoa municipality, in relation to natural erosive processes and also how the anthropic actions interfere on the system resilience. For that, the vulnerability degree of the foredunes system to erosion will be determined through the application of a vulnerability index, which considers the natural characteristics of the environment and the influence of anthropogenic impacts.

Study Area

The northern coast of Rio Grande do Sul, as well as the whole extension of its coastline, present characteristics that are quite different from the rest of the Brazilian coast, regarding geology, landscape and ecologic singularity.

According to the delimitation established by the Coastal Management Program (*Programa de Gerenciamento Costeiro*) of the Environmental Protection Foundation of Rio Grande do Sul State (FEPAM), known as GERCO-RS, the Hydrographic Region of the Coast is divided in three sub regions: Northern Coast, Central Coast and Southern Coast. The Northern Coast, where Capão da Canoa is located, has an extension of 120 km of shoreline and a superficial area of 3700 km².

The geology of Rio Grande do Sul's coastal plain is recent, formed by an extensive sedimentary plain from the Quaternary. The sedimentary facies and the geomorphological features are mostly unconsolidated and still under formation, and, therefore, subjected to erosion and reworking by exogenous agents. Such qualities make them fragile and particularly vulnerable to pressures of use and land occupation, related with the recent urbanization process of the northern coast.

The current coastline presents an overall orientation NE-SW, with sandy, semi rectilinear and continuous beaches, predominantly dominated by waves. It is characterized by long period undulation derived mainly from the SE and by surges (which result from the local wind action) derived from the E-NE. Especially during fall and winter, the

normal wave regime is episodically disturbed by storm waves associated with the passage of cold fronts from the south (TOMAZELLI e VILLWOCK, 1992).

The area presents a micro tidal regime, controlled by an astronomical tide whose average amplitude is around 0.5m. It also presents the influence of meteorological tides, which can reach from 1.2m in Tramandaí (Almeida et. al., 1997) to 1.6m in Rio Grande (PARISE et. al. 2009), being responsible for the coast erosion, since they cause the rise of the sea level above the astronomical tidal prism, producing even greater variations when associated with syzydy tides. According to the morph dynamic sequences, the beaches of Rio Grande do Sul's northern coast vary between intermediate and dissipative (TOMAZELLI AND VILLWOCK, 1992; TOLDO JR. ET AL., 1993; WESCHENFELDER, 2002; GRUBER et al., 2003).

On this portion of the coast, there is a sequence of high ecologically valued environments, with significant biological production, and with valuable landscape importance. Among these environments, the sea beaches, the foredunes, the dune fields, the wetlands, and the notorious string of lagoons, the swamp forests, the sandbanks, and even the Serra Geral foothills, formed by the valleys of the Maquiné and Três Forquilhas rivers, which in turn, are home to the Atlantic Forest biosphere reserve, can be considered.

The northern coast is strongly impacted by urbanization and owes its significant growth to the attraction of vacationers, who seek for a second residence in the coastal municipalities. Nineteen municipalities compose the northern coast of the State, whose economies are related to civil construction and summer activities. This fact has boosted a large investment in urban infrastructure, although still deficient in terms of sanitation, and an occupation that lacks guidelines and planning. These factors characterize the environmental impact suffered by the coastal environments, aggravated by the protruding seasonal variation of the population. This population comes from the capital and other regions of the State looking for leisure and recreation.

The Capão da Canoa municipality covers an area of 97 km². Besides the Capão da Canoa beach, the municipality is composed by the districts of Capão Novo, Arroio Teixeira and Curumim.

Methodology

The vulnerability assessment was done through the application of a vulnerability control list, for the determination of areas whose resilience is under threat, therefore, a priority to intervention actions. This evaluation occurred in two stages through field trips in September 2009 and February 2010. The shoreline of 18 km was sub divided in profiles with 250 meters parallel to the coastline, totaling 71 profiles rated and analyzed. The route was from north to south, so that profile 1 is located in the Navegantes neighborhood, on the border with Xangri-Lá municipality, and profile 71 is located in Curumim, on the border with Terra de Areia municipality.

The main parameters that summarize the systematic condition of the dunes were rated with grades from zero to 4, where zero represents equilibrium conditions, and 4 an advanced stage of degradation (TABAJARA et. al., 2012). The parameters were grouped in 4 sections:

Section A (dune morphology): the geomorphologic condition influences the regeneration capacity of the dunes after environmental stress events and it is related to their extension and volume. The larger the system and the greater the sediment availability, the better the ecologic and geomorphologic relations will be, allied with the protection against aeolian and sea erosions (WILLIAMS et al., 2001). Parameters: superficial area; dune width; maximum dune height; formation of scarps; evolutionary stages; and steepness on the frontal sea face.

Section B (beach condition): refers to the backshore, related to the direct sediment supply to the frontal dunes. The beach width is directly proportional to sediment availability. Parameters: backshore width; sand supply; beach face gaps; width of the gaps on the beach face; embryo dunes; coastline/drift orientation; and concavity index.

Section C (surface characteristics of the seaward 200 m): contains more embracing parameters that synthetize the biophysical scope. Parameters: blowout areas inside the system; sand scape from the system to the mainland; gaps on the dunes system; sea side of the vegetated dune; if the recent deposited sand was colonized by *Blutaparon portulacoides*; impervious cover; and existence of exotic vegetation and spillways.

Section D (pressure of use): elements of anthropogenic nature, which directly affect the foredunes equilibrium. Parameters: vehicles accesses; pedestrian paths density; urbanization stage; urbanization level; urbanization position; and presence of kiosks on the beach.

After establishing the indexes, the profiles were grouped in levels (LARANJEIRA, 1997):

Level 1 (0-20%) – Vulnerability level where the transformation degree of the dunes system does not put its self-healing capacity under risk; the degradation state of the features does not exceed the resilience threshold; low sensibility.

Level 2 (20-40%) – Vulnerability level where change signs can be perceived on the system; the low sensibility starts to accentuate.

Level 3 (40-60%) – Significant degradation signs can be perceived; a certain restriction of use is necessary. The dunes' features are on the resilience threshold.

Level 4 (60-80%) – Very significant pressure mechanisms can be observed; the dunes' features do not present resistance mechanisms against the negative effects; sensibility is high.

Level 5 (80-100%) – Severe and widespread degradation effects are evident. The degradation level is extremely high, compromising the character of the landforms. Resilience threshold is exceed.

According to this classification, all the profiles analyzed during winter 2009 and summer 2010 were classified on the levels 1, 2, 3, and 4. A level 5 of vulnerability was not found.

Results and discussion

Vulnerability is the state of susceptibility to damages caused by stress exposition associated with environmental and social changes and the absence of adaptation capacity (ADGER, 2006). In this project, the term is associated with a group of conditions and attributes that induce the dunes system to erosion and degradation processes, as well as the mischaracterization of the beach system in equilibrium.

Through the surveys done in September, 2009, it was possible to evaluate the vulnerability indexes (VI) behavior of the foredunes on the Capão da Canoa shoreline at the end of the winter. At this time of the year, all the incident phenomena typical of this season would already have reached their maximum degree of occurrences.

Main winter variables

At first, only the profiles of the administrative district area will be analyzed, the profiles between 1 and 14. The factor that mostly answers to the alteration of the dune systems in the administrative district during the winter is the beach condition, with an average variation of 61%. This factor, however, does not represent a mode on the vulnerability behavior, since it is followed by the factors "A": dune morphology (60%), pressure of use (50%), and characteristics of the 200 m next to the sea (50%). The 14 profiles of this highly urbanized and densified sector of the Capão da Canoa shoreline present an average VI of 50%, therefore, correspond to the level 3 of vulnerability, on the resilience threshold of the frontal dunes, which are quite degraded or even extinct due to urbanization.

The profiles that contribute most to the system vulnerability on this sector are the profiles 6, 7, 8, and 9 (*Zona Nova* neighborhood).

The presence of the boardwalk and the *Baronda* structure (commercial unity) represents enormous imbalances on the beach-dune system, since the dunes were virtually extinguished on this sector. Therefore, the beach and the constructed structures are exposed to sea erosion, not allowing any sediment stock for the system. Due to the substitution of much of the dunes area for asphalt pavement in profile 6 and on the adjacent profiles, the dune morphology parameter (A) attributed was 100%, indicating a really high global vulnerability for this sector.

Profile 23, located in the *Jardim Beira Mar* coastal town, is representative of a recurrent characteristic of the dunes morphology during winter, when they are more susceptible to the formation of scarps, caused by the meteorological tides.

Besides of the erosive face found on the foredune, there is also the presence of exotic vegetation, such as the *Acacia trinervis*. The presence of exotic species creates a vulnerability factor, because they compete with the native vegetation, preventing the latter of fixing, which facilitates the sand loss by aeolic and sea action (PORTZ, 2010).

The analysis of some winter profiles aims to demonstrate the main partial indexes (PI) that act in a more representative way on the dunes system. The general behavior of the VI over the shoreline during winter is presented in Figure 1.

Through the analysis of the VI curve of Capão da Canoa's shoreline, it can be concluded that the vulnerability peaks for the winter agree with the most urbanized sectors of the shoreline. It is possible to observe that the highest vulnerability peak occurs on profile 6, where the boardwalk has substituted most of the foredune. This peak is followed by profile 29's (*Praia do Barco*) peak, characterizing administrative district's dunes as extremely vulnerable. The curve decreases abruptly on the intercity spaces without the presence of consolidated urbanization in the south-north direction, going up again in profiles 42 (Capão Novo, station 4), 54 (Arroio Teixeira), and 70 (Curumim).

Main summer variables

The surveys carried out for the determination of the summer VI's of the Capão da Canoa foredunes occurred in February 2010. The month of February, after the carnival celebrations period, represents the end of the most expressive summer time. It culminates with the maximum vulnerability for the summer, after all the impact generated by the intense use of the beaches for recreational purposes. The profiles that include the most vulnerable sectors of the dunes are 40, 41, 42 (Capão Novo), 68, 69, 70, and 71 (Curumim).

Profile 71 is used to exemplify a typical summer profile for the Capão da Canoa shoreline. This profile comprises a zone of 250 m in the Curumim district and is characterized by a consolidated urbanization, with the predominance of horizontal urbanization and secondary residence houses, occupation density from medium to high (STROHAECKER, 2007), and, therefore, high potential of visual and wastewater pollution.

The accentuated pressure of use in this sector represents the most significant PI, since there is a high number of houses, restaurants and kiosks on the beach strip and on the post-dune, reducing the width of the foredunes, which is 26m in average. The partial vulnerability indexes by section for the Capão Novo and Curumim districts represent the importance of the pressure of use on the frontal dunes equilibrium alteration, with an average variation of 58%. The spatial distribution curve of the vulnerability levels in February 2010 is shown in Figure 1.

The monitoring of the environmental conditions of the frontal dunes must be continuous and the data must be systematically collected so that coastal zones stakeholders can be subsided with the best quality and quantity of data possible.

The nature of the changes on the erosion and accretion stages of the dunes has been studied and reported in the scientific literature (ARMAROLI et al, 2013; PYE e BLOTT, 2008; ANTHONY et al, 2006; SAYE et al, 2005). In Rio Grande do Sul, there is a dynamic equilibrium between the low wave energies and the formation of an accretion profile on the beach (and consequently, greater availability of sediments to the foredune system), and the high-energy wave conditions that generate erosion profiles (TABAJARA et al., 2004; PORTZ et al 2010). The intensity of these processes, however, may vary according to the level of degradation of the frontal dunes, which is a result of the quality of the anthropic factor, expressed through planning and land use planning, or by the lack of them. Therefore, it is imperative to analyze the seasonal changes on the vulnerability

indexes behavior of the frontal dunes, aiming for the improvement and the quality of decision making by the government.

Winter and summer vulnerability indexes

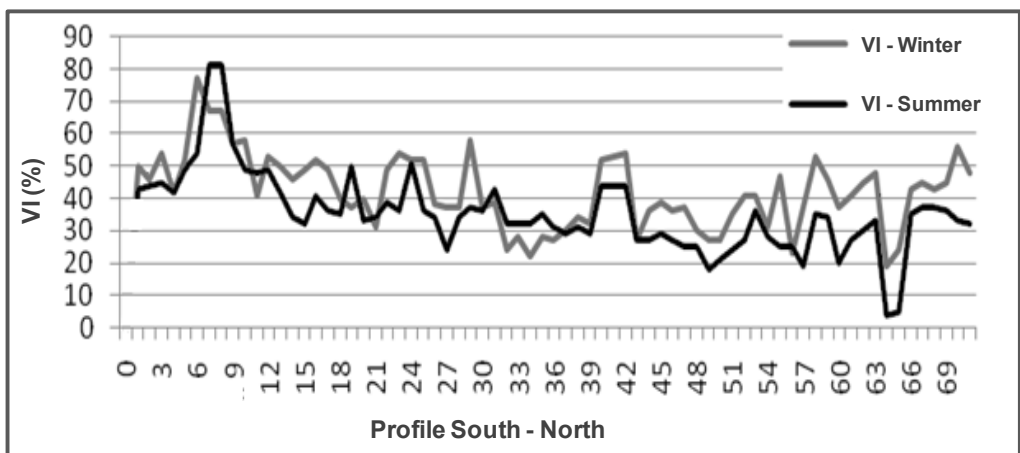
For the visualization of the VI behavior curve of winter and summer along Capão da Canoa's shoreline, the two graphs were overlapped (Figure 1).

The analysis of this graph allows an inference in the superiority of the winter vulnerability indexes, which are, on average, 7% higher than the summer indexes. The points where this does not occur are liable to investigation and continuous monitoring so that linearities and discontinuities of this behavior can be estimated.

The arithmetic mean of the values related to the winter and summer vulnerability indexes on each profile were calculated for the determination of the vulnerability mean during the year. Through the attribution of mean values, it was possible to divide the shoreline in sectors according to the vulnerability levels on levels 1 (0-20%), 2 (20-40%), 3 (40-60%), and 4 (60-80%) (Figure 2). From this division, it is possible to elect the priority areas for dunes management, where the degradation processes threaten the resilience threshold of the foredunes.

Through the graphic observation generated by the surveys, it was possible to confirm that the most vulnerable sectors agree with the most urbanized zones of the municipality's shoreline, in particular, the profiles located on the central (Centro) neighborhood. The mean vulnerability index analysis will be done on the profiles considered the most vulnerable and liable to intervention through dune management techniques.

Figure 1. Behavior of the winter and summer vulnerability indexes along the shoreline.



Profiles 1, 6, 7, 12, and 13 were analyzed for the administrative district. Profile 1 has a level 3 of vulnerability, since its average index is 47%. The factors that most contribute for the sensibility of the dunes on this sector are section B (beach condition) and D (pressure of use). The first one is more significant during winter, with a positive variation of 30% in relation to summer; the latter has a positive variation of 14% in relation to winter.

The beach condition in this sector is quite modified during winter due to the sediment stock removal from the sub aerial beach during meteorological tides. A clear indicator of this fact is the absence of incipient dunes during winter in this sector. The pressure of use increases during summer (from December to February), as kiosks, that degrade the beach environmental quality due to waste accumulation, and modifications to the sand transportation of the berm stocks, are implemented. After this summer period, this waste tends to accumulate in the dunes sector through the trapping of the residues on these regions and their fragmentation into smaller parts (PORTZ, 2011a).

It is possible to observe in Figure 3 – profile 1, the attempt to change a spillway direction, through the implantation of wood stakes (winter, 2009) because they did not present the same structural integrity during the field survey in February, 2010.

According to Figure 3, profiles 6 and 7 have a high vulnerability degree and are on level 4. All the sections present a high partial vulnerability index, attenuated by parameter B (beach condition), since these sectors presented a satisfactory backshore width at the time of the summer survey (approximately 60 m). The strong pressure of use that mischaracterizes the beach-dune system weakens the sector against winter phenomena incidents (according to the predominance of the winter polygon).

Profile 12 belongs to level 3 (40-60%) of vulnerability. The presence of the pluvial drainage channel (spillway) interrupting the lateral continuity of the foredunes cord is responsible for the high PI of each section. The channel flow causes erosion of the dunes' lateral walls, and interrupts the sediment supply to the dunes, since this sand flux on the backshore occurs through saltation and rolling. Sometimes, the spillways might present a really high flow increase, which may destabilize the slopes of the lateral walls that follow the flux of the channel. These areas are also considered more vulnerable to sea level rise (PORTZ et al, 2014).

Even though profile 13 (Figure 3) presents a typical vulnerability index for these area profiles, the most significant characteristic is the sand fugue from the dunes system to mainland. This profile presents an interesting conflict point, since the factor that mostly modifies the system equilibrium during summer is not the pressure of use (61%). The urbanization position, which occupies the post-dune area is associated with a high density of pedestrian paths, which degrades the vegetation, and releases sand for aeolian transport, creating a situation of progress of the deposition lobes and the formation of a wind deflation corridor that reaches the street and houses.

In Capão Novo, profiles 41 and 42 are the most relevant since they present a high mean vulnerability index. This sector has, predominantly, secondary residence houses, and presents an intermediary potential of visual and wastewater pollution. The comparison between the vulnerability indexes behaviors of these profiles shows that the biggest variation occurred on section A, approximately 20%. The morphology of the foredunes

Figure 2. Division in sectors according to their average vulnerability indexes.

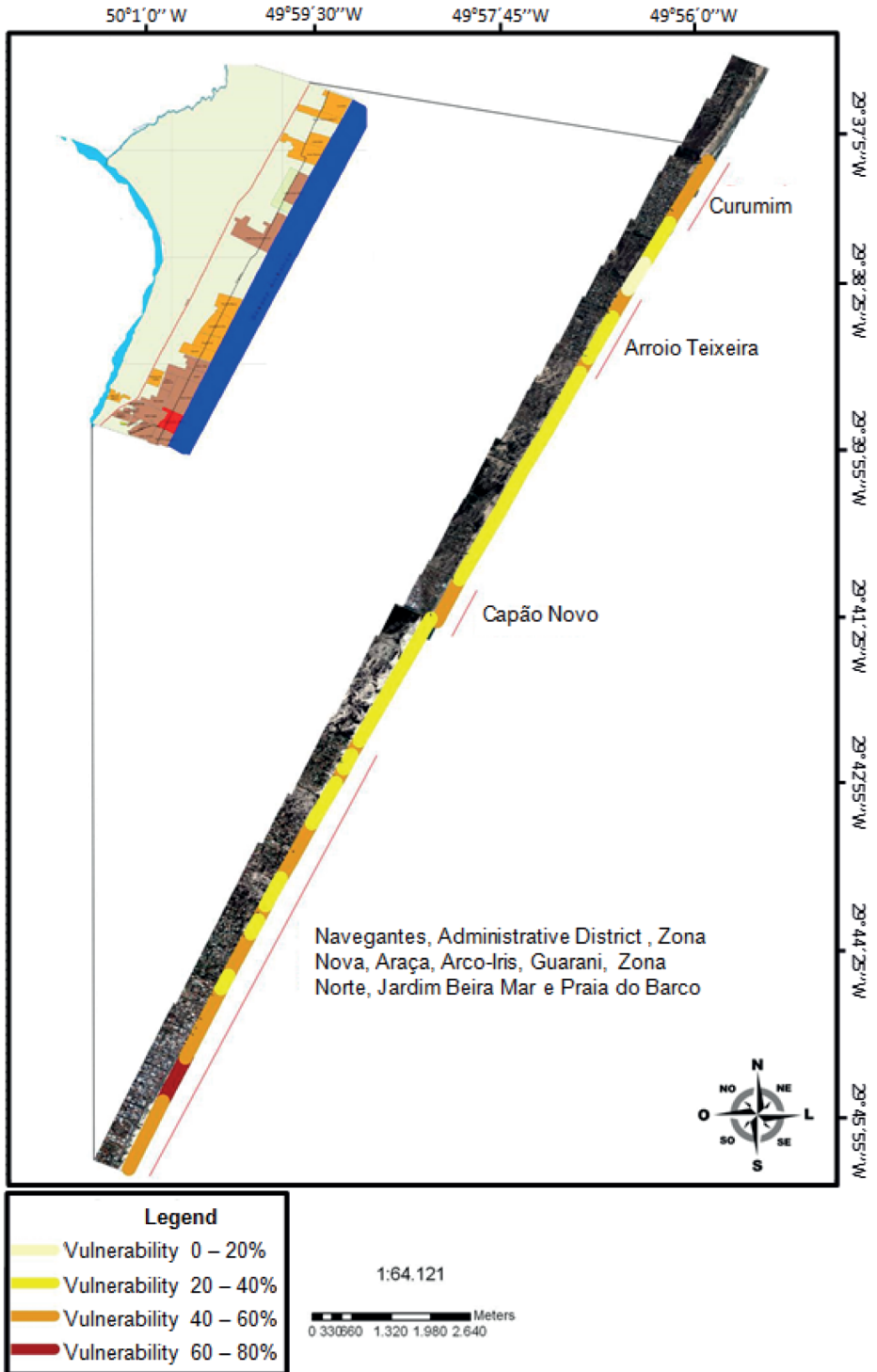
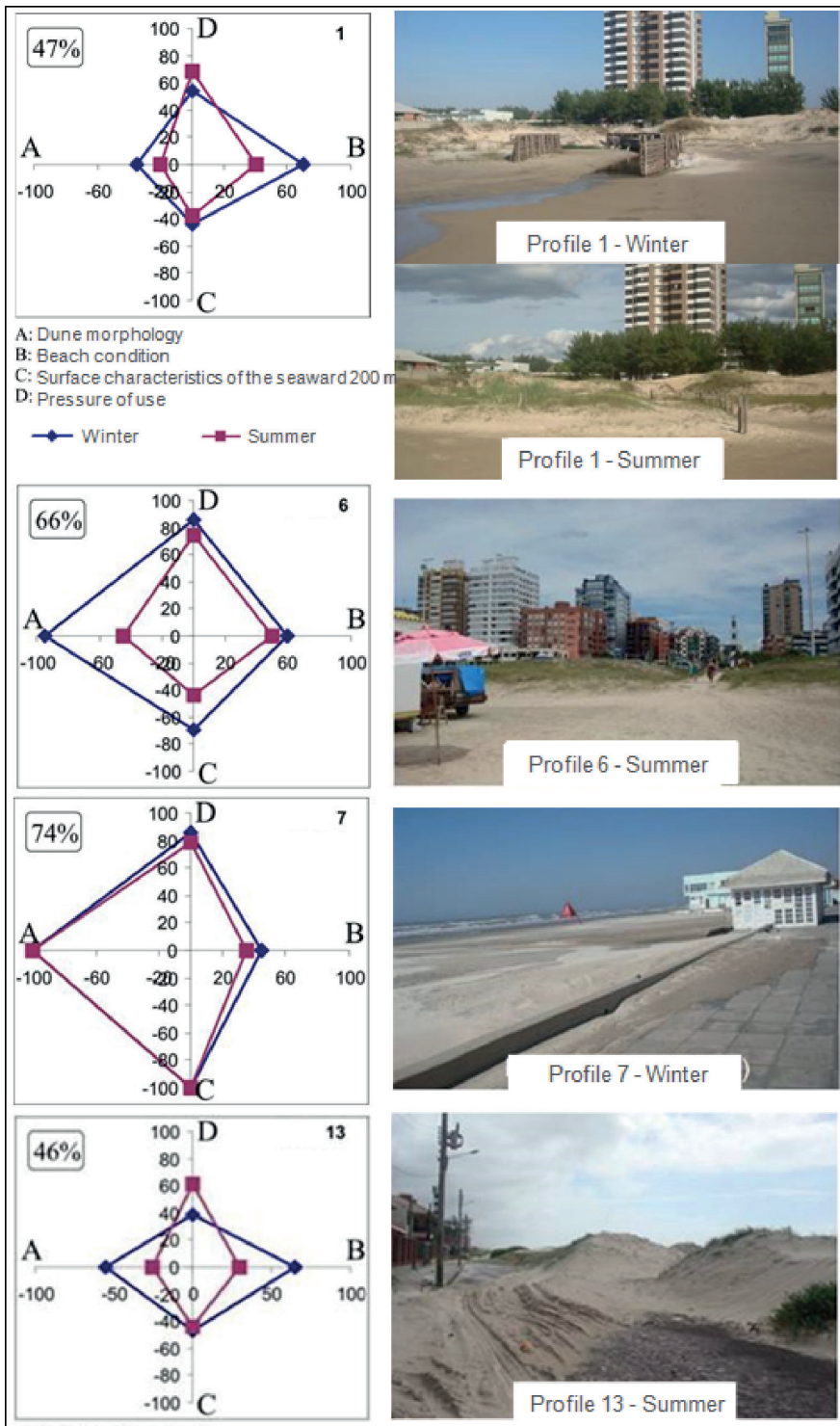


Figure 3. Overlap polygonal graph of the winter and summer vulnerability indexes.



has been modified by the presence of sports fields and leisure clubs on the post-dune, reducing drastically the width of the dunes strings, and exposing them to a higher vulnerability during winter.

In Arroio Teixeira, the highest vulnerability point is associated with the presence of a big spillway, correspondent to profile 58. In this sector, the spillway drains a lot of water, increasing the convexity of the beach and the lateral erosion of the frontal dunes. Due to the spillway influence, together with the smaller backshore width on the north area of the municipality, the PI that presented the highest winter/summer variation was section B (35% variation), followed by section C's PI (18%), due to the lack of colonization of the deposited sand by pioneer species such as the *Blutaparion portulacoides*. The high PI variation on section B might be related to the spillway flow increase during winter, associated with the removal of sediments on the backshore.

The only profiles on Capão da Canoa's shoreline that present a level 1 (0-20%) of vulnerability, representing a great degree of morpho-ecological equilibrium, are located next to *Arroio Teixeira*.

Phenomena incident on the foredunes during winter and summer

It is possible to observe through the analysis of the mean winter and summer vulnerability indexes that the mean winter vulnerability index for all the profiles on Capão da Canoa's shoreline varies around 7% in relation to the mean summer vulnerability index for the same area. However, it is important to assess the contribution of each section and their partial vulnerability indexes, so that one can infer the nature of the phenomena that aggravate them.

The highest mean partial vulnerability index during winter corresponds to the section B (beach condition) (mean PI: summer 33; winter 59), whereas the highest mean PI for the winter belongs to section D (pressure of use) (mean PI: summer 42; winter 33). These data corroborate the knowledge about the morphodynamic of the open beaches dominated by waves, in their seasonal variations, as well as about the fact that there is an intense use of the beaches during summer for leisure activities, characterized by the predominance of the section average PI during summer.

The effect of undertows on the beach-dune system

The extra tropical regions of both hemispheres are characterized by continuous migration of synoptic characteristics, resulting in a high atmospheric variability in short term. The anticyclones and associated fronts have a considerable impact on these regions (JONES and SIMMONDS, 1993). The south coast of Brazil is submitted to positive sea level rise due to the influence of winds from the SE and S quadrants, associated to the passage of frontal systems and cyclone vortices (PARISE et al, 2009).

The extra tropical cyclones (low pressure), resultant from frontal systems, create differences on the atmospheric pressure gradients, producing strong winds that create the meteorological tides. These, in turn, transfer energy to the sea in the form of undulation,

occurring on the Brazilian coast especially between April and October (TABAJARA et al., 2004).

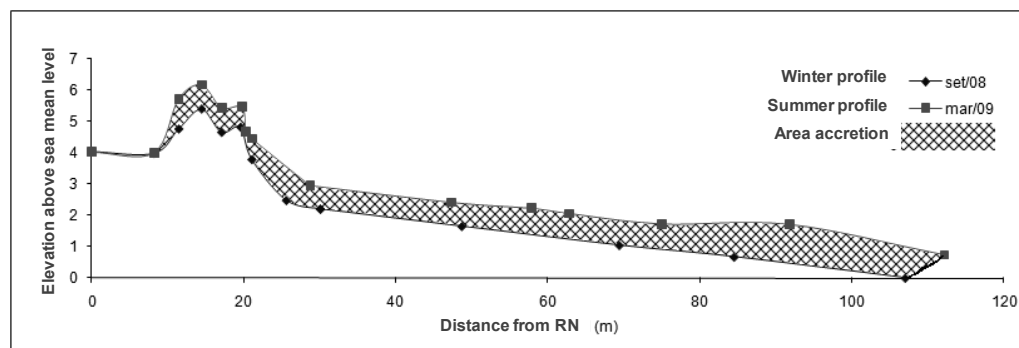
The beaches on Rio Grande do Sul's coast present a dissipative morpho- dynamic profile, which results in a beach profile with low declivity. Due to the passage of frontal systems and the cyclogenesis over the ocean during these events of high energy levels, there is a stacking of the wave train on the coast, scarping the sea face of the dune (TOMAZELLI e VILLWOCK, 1992), as well as the erosion of a considerable part of the sediment stock on the backshore. The Cassino beach, south coast of RS, for example, presents a seasonal behavior, with episodic erosion associated with high energy level events more frequent during winter, and long periods of accretion related to the normal hydrodynamic regime (PARISE et al, 2009).

The impact on the dunes system, and, consequently the eroded sand volume, depend on the frequency and intensity of each event (OVERTON e FISHER, 1988). The incidence of meteorological tides creates gaps and scarps, besides de removal of sediment from the subaerial beach to the underwater beach. This process also facilitates the aeolian erosion that will later create deflation basins (HESP, 2002). The resulting impacts of the meteorological tides can also be identified by the presence or absence of embryo dunes. These formations are recently developed by the sand deposition in the middle of some obstacle, normally pioneer vegetation (HESP, 2000).

The beginning of spring marks an energy regime of the waves that is more moderate and the recomposition of the beach profile (TABAJARA et al, 2004). Consequently, the vulnerability indexes are lower during summer, when the system reaches its maximum accretion, and higher during winter, especially the partial vulnerability indexes of the indexes A and B. The dynamics of sediment removal and restoration on the backshore and on the dune can be illustrated by topographic profiles perpendicular to the shoreline measured during winter and summer (Figure 4).

The dunes system recuperation processes begin immediately after the passage of storms, with the arrival of new sediment supply. This recuperation process, depending on the intensity and frequency of the events, can begin immediately after the storm passage and stay for more than two years after the storm (SUANEZ, 2012). In Rio Grande do Sul, between the years of 2005 and 2006, during the monitoring for the Dunes Management project in Xangri-Lá municipality, a catastrophic meteo-oceanographic event was registered. The event was produced by the passage of an extra tropical cyclone, triggering a sharp erosion process; the reconstruction processes were inefficient during this period (PORTZ, 2010).

Figure 4. Elevations of the dune and backshore, Capão da Canoa Administrative District.



Seasonal Population

The highest partial vulnerability index (PI) registered during summer belongs to section D, pressure of use, with an average variation of 43%. It is not difficult to infer about the causes of this section's contribution preponderance on summer, since the period is marked by intense seasonal flux of population that goes to the coast area, pressuring the coast natural resources significantly.

The tourism and summer activities have a high impact on the coast dunes. In Capão da Canoa's case, the high occupation density sectors also concentrate a high density of pedestrian walkways, accesses for vehicles, and structures on the shoreline, such as fixed and mobile kiosks, which contribute to the destruction of the vegetation, and submit the fragile frontal dunes to aeolian erosion from the SE winds.

The municipality lacks exact data about its population, however, some estimates were done for the year of 2005. Based on the average water and electricity consumption per habitant, as well as the production of solid waste, a seasonal population of 100.000 people was accounted. Meanwhile, the permanent population estimated by the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística - IBGE*) for the same period was 37800 people (STROHAECKER, 2007). It is important to mention that some of the pressure of use impacts are permanent, such as the presence of highways, streets, and the position of the urbanization. Whereas others are temporary, such as the increase of pedestrian walkways. The latter constitute the focus of management and handling strategies essential for the maintenance of the frontal dunes systems (WILLIAMS, 2001).

The human pressure over the coastal environments is intensified by the social tendency of moving closer to the coast area. The increasing pace of human alterations on the landscape and the human potential of reconstructing nature to provide services and ecological functions require that the anthropogenic activities are considered in several ways that allow them to become compatible with nature (NORDSTRON, 2008).

Adding the processes resultant from the natural dynamic, which induce a high vulnerability, especially during winter months, with the anthropogenic processes established during summer, the establishment of techniques to reduce the environmental losses and maintain the natural functions of the dunes protection system against storm events becomes necessary. Considering the erosion processes, the lack of actions that minimize this process, and the lack of commitment of the beach users, that induce the scenic mischaracterization of the environment (PORTZ, 2010), an environmental degradation scenario develops. This scenario opposes the economic situation of this municipality that depends directly on tourist and summer activities.

In order to minimize the damage caused on the dunes system, the state environmental agency (FEPAM) requires, since 2004, the development of dunes management plans. This plan, controlling the forms of use and appropriation of the dunes space, and controlling the vegetation degradation, highlights the implications of the Brazilian Forest Code (Article 3) that considers this environment as a permanent preservation area (PORTZ et al 2011).

With the implementation of the plans by the municipalities, an increase on the conservation and management of the dunes ecosystem is expected, through the control and planning of the activities on this environment and the recuperation of the areas under degradation process.

Final considerations

The quality of the decision making of the integrated coastal zones management depends on information availability, and on constant environmental monitoring together with socio-economic and cultural factors involving the participation and awareness of the population that occupy the areas under management.

The methodology that involves the use of the coastal dunes vulnerability control list appears to be quite trustable and its results provide an in-depth analysis of the main existing problems and conflicts. The delineation of the problem occurs in a fast and economic way, allowing fast access and interpretation of the elaborated information, helping managers and communities with the identification of the parameters that mostly modify the equilibrium of these natural systems. It is important, however, that there is a continuity of the coastal dunes vulnerability monitoring, preferably also using resources of more in-depth studies, such as topography surveys, and macro-scale analysis, for example, the estimation of sea level rise elevation and the long-term monitoring of the coast's morph dynamics.

The summer and winter surveys showed which parameters accentuate the environmental degradation of the frontal dunes in their seasonal differences. This configures the methodology as an excellent indicator from where managers should focus their actions. The cyclical nature of erosion and accretion processes of the beach profile can be modified by the accentuated human pressure of use on coastal environmental and, aggravated by recreation and tourism activities. The intricate relation between natural dynamics and anthropogenic influence on some environments, require from several society sectors

an increasing mobilization for the creation of management plans. The decision making process must be guided by the evidence obtained through environmental monitoring, precise objective establishment, and evaluation of strategic options.

The delineation of priority areas for the management - which is about a homogeneous and continuous group with high vulnerability levels ($IV > 60\%$), due to an equivocated urbanization that has advanced over the dunes - guides the focus of the actions for maintenance of the natural equilibrium by the municipalities.

The main point about the seasonal evaluation of the dunes system characterization is the understanding of the relative superiority of the winter vulnerability indexes, which are on average 7% higher than the summer vulnerability indexes. This modifies the consensus about the human interference being the main vulnerability vector on this environment. Another consideration is the differentiation of the partial contribution of the indexes; the highest mean winter PI corresponds to section B (beach condition), whereas the highest mean summer PI belongs to section D (pressure of use).

The sum of these conclusions must be taken into consideration in the delineation of strategies for the dunes management, which are currently focused only on the summer period and only to minimize the effects of the beach use.

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IMPACTS ON THE DUNES SYSTEM: NATURAL DYNAMIC VERSUS ANTHROPOGENIC INTERFERENCE

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Abstract: The shoreline of Capão da Canoa, RS, alternates densely populated areas with non urban empty spaces that still have their natural features preserved. This paperwork aimed to evaluate the foredunes vulnerability, by field evaluation along the shoreline in wintertime and summertime, using a field checklist. After rating some parameters, a Vulnerability Index was established for each profile. The highest values matched the most densely populated areas in that municipality, due to the position of the urban area that often shortens the width of the foredune ridges. The superiority of the wintertime vulnerability index when compared to summertime, changes the consensus about the human interference as the main vector of vulnerability. The major factors contributing to foredune degradation were: beach condition during winter time and use pressure, during summertime, indicating the high vulnerability associated with some profiles along the shoreline.

Keywords: foredunes, vulnerability index, Capão da Canoa

Resumo: A orla de Capão da Canoa, RS, intercala áreas de alta densidade ocupacional com áreas não urbanizadas que preservam suas características naturais. Neste trabalho, buscou-se analisar o índice de vulnerabilidade das dunas frontais, a partir de levantamentos de campo realizados no inverno e verão, utilizando-se uma lista de parâmetros. A partir da taxação destes, atribuiu-se um índice de vulnerabilidade para cada perfil. Os valores mais altos coincidiram com as áreas mais urbanizadas do município, devido à posição da urbanização que reduz a largura dos cordões de dunas frontais. A superioridade dos valores do índice de vulnerabilidade de inverno ao de verão altera o consenso sobre a interferência humana como principal vetor de vulnerabilidade. Os fatores que mais contribuíram para a degradação das dunas frontais foram: a condição de praia, no inverno, e a pressão de uso, no verão, indicando a alta fragilidade de alguns perfis ao longo da orla.

Palavras-chave: dunas frontais, índice de vulnerabilidade, Capão da Canoa

Resumen: El litoral de Capão da Canoa, RS, alterna zonas densamente pobladas con espacios de vacíos urbanos que preservan sus características naturales. El objetivo de este artículo fue evaluar el grado de vulnerabilidad de lo cordón dunar, por la evaluación de campo en invierno y el verano, utilizando una lista de verificación de campo. A partir de la obtención de los parámetros, un índice de vulnerabilidad se estableció para cada perfil. Los valores más elevados corresponden las zonas más densamente pobladas en ese municipio, tanto en invierno como en verano, debido la posición de la zona urbana, que a menudo reduce el ancho de lo cordón dunar. Los principales factores que contribuyen a la degradación de dunas litorales fueron: las condiciones de la playa durante el invierno y los usos humanos, durante el verano, lo que indica la alta vulnerabilidad asociada con algunos perfiles a lo largo del litoral.

Palabras clave: cordón dunar, índice de vulnerabilidad, Capão da Canoa
