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Richness and community structure of sand dunes (restinga) in Santa Catarina: subsidies for ecological restoration

Riqueza e estrutura comunitária de uma restinga sobre dunas em Santa Catarina: subsídios para o restauro ecológico

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ABSTRACT
The coast of Balneario Piçarras city (Santa Catarina) is being constantly degraded by human action. This study aimed to characterize the richness and vegetation structure of two areas of herbaceous restinga (preserved and degraded) of the coastal plain of this city. The flora was mapped by using the patrolling method. Identification was done by comparative morphology and specialized bibliography. The phytosociology was based on the plot method with allocation oriented parallel to the coast line. There were 48 species, 44 genera and 22 families identified. Fabaceae, Asteraceae and Poaceae are the richest families. The H' index was 3.9 in the preserved area and 2.1 in the degraded area. The community structure was represented by eight and 16 species in the degraded and preserved areas, respectively. In degraded areas, species as *Spartina ciliata*, *Ipomoea pes-caprae*, *Sphagneticola trilobata* and *Paspalum vaginatum* have the greater importance of coverage, structuring the community. In the preserved area, the organization structure of the community is given by *Canavalia rosea*, *Remirea maritima*, *Stenotaphrum secundatum*, *Spartina ciliata* and *Acicarpha spathulata* species. These species are considered pioneers and with a great potential of fixing dunes, which reflects their importance to the achievement of a future restoration work of the damaged area of the restinga in question.
Keywords: Coastal plain; floristic; phytosociology; recovery of degraded areas.

RESUMO
O litoral de Balneário Piçarras (SC) vem sendo constantemente degradado pela ação antrópica. Este estudo objetivou caracterizar a riqueza e a estrutura da vegetação de duas áreas de restinga herbácea (preservada e degradada) da planície costeira desse município. A flora foi mapeada pelo método de caminhamento. A identificação deu-se por meio de morfologia comparada e bibliografia especializada. A fitossociologia baseou-se no método de parcelas com alocação orientada paralelamente à linha da costa. Identificaram-se 48 espécies, 44 gêneros e 22 famílias. Fabaceae, Asteraceae e Poaceae são as famílias mais ricas. O índice H' foi 3,9 na área preservada e 2,1 na degradada. A estrutura comunitária foi representada por oito e 16 espécies nas áreas degradada e preservada, respectivamente. Na área degradada as espécies *Spartina ciliata*, *Ipomoea pes-caprae*, *Sphagneticola trilobata* e *Paspalum vaginatum* possuem a maior importância de cobertura, estruturando a comunidade. Na área preservada, a organização estrutural da comunidade é dada pelas espécies *Canavalia rosea*, *Remirea maritima*, *Stenotaphrum secundatum*, *Spartina ciliata* e *Acicarpha spathulata*. Tais espécies são consideradas pioneiras e de grande potencial fixador de dunas, o que reflete sua importância para a realização de um futuro trabalho de recuperação da área degradada da restinga em questão.
Palavras-chave: Fitossociologia; florística; planície costeira; recuperação de áreas degradadas.

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INTRODUCTION

Restinga is the denomination given to the set of plants, distributed in mosaic, associated with Quaternary coastal sand deposits and rocky coastal habitats. Such communities are found in surroundings of beaches, sand bars, dunes, depressions and transitions to local environments (BRASIL, 2009; MAGNANO *et al*., 2010). The sand dunes along the Brazilian coast have marked differences in their physiognomy, structure and composition and may include, according to the predominant formation, herbs, shrubs and trees (LACERDA *et al.,* 1984; ROCHA & BERGALLO, 1997; ARAÚJO, 2000). In general, the vegetation reflects the restrictive conditions for its development, emphasizing high salinity, low fertility and low moisture of the soil, high solar radiation and strong winds. Thus, in sand dunes, plants have adaptive strategies to these limiting factors, being typically xerophytes (ARAÚJO, 1992). Due to these factors, sand dunes are considered an extremely fragile domain, which creates great concern about their conservation and management (ARAÚJO *et al*., 2004; GUEDES *et al*., 2006).

The sandbank vegetation plays an important role in stabilizing dunes, retaining and fastening the sediments carried by the winds to the mainland, thus keeping the sand on the beach environment (CLARK, 1977; CORDAZZO *et al*., 2006). Even with such importance, the sand dune`s ecosystem has suffered recurring human impacts (THOMAZI *et al*., 2013).

The sand dunes are currently exposed to different sources of degradation that have reduced their areas continuously. The most serious are the real estate expansion, including land grabbing, the deposition of waste on vegetation and illegal removal of sand (LEMOS *et al.* 2001).

The degradation of these environments can initiate a process of erosion creates unintended consequences, such as loss of land of economic, social or ecological value; disappearance of narrow beaches; loss and imbalance of natural habitats; increased frequency of flooding resulting from back sweeps; increased salt water intrusion in coastal aquifers; loss of landscape and tourism potential of the region; exposure of coastal zones to ocean energy and risks to residents (PORTZ, 2012). In Santa Catarina, the coastal plain is characterized by the presence of sandbank areas, heavily impacted by human activities but still well preserved, which are considered places of great interest in biodiversity protection, as the sandbank of the Acaraí State Park, located in São Francisco do Sul (PROBIO, 2003).

Not differing from many other coastal regions of the country, the coastal city of *Balneario Picarras* (SC), with a length of 7 km, is being constantly degraded by human action. Due to this degradation and lack of ecological and physiognomic data from several stretches of the Brazilian coast, the scientific community began to worry and to develop several studies on coastal ecosystem (ASSIS *et al.,* 2004). To propose recovery actions is a fundamental action. For this reason, it is necessary to know the species present in the environment to select those that will be used and to employ appropriate techniques to the restoration of sandbank, since it is considered one of the most difficult environments to be recovered, by virtue of the substrate nature (RODRIGUES *et al.,* 2007). Surprisingly, sandbanks are areas with low information, not only in scientific terms about biodiversity, but also around the degree of conservation of remaining areas (ROCHA *et al*., 2003). The scarcity of information on the physiological ecology of species sandbank or even flora and community structure over dunes in many coastal municipalities of the country, especially in the state of Santa Catarina (MELO JR., 2015), hinders the most appropriate choice of restoration methods and the species to be used (RODRIGUES *et al.,* 2007).

Based on these arguments, the present study aimed to characterize the specific diversity and structure of vegetation in two areas of sandbank on dunes in varying degrees of preservation of the coastal plain of the city of *Balneario Picarras,* Santa Catarina, Brazil.

MATERIAL AND METHODS

The study was conducted in the city of *Balneário Piçarras*, Santa Catarina, in two areas of sandbanks on dunes, with varying degrees of conservation, one preserved (26°45'36.79"S and 48°40'22.80"W) and the other degraded (26°43'56.31"S and 48°40'19"W) (Figure 1). According to Köppen classification, the climate of the study area is mesothermal humid with hot summers and no dry season (CFa). It has an average annual temperature of 20 °C and rainfall range of 1600-1800 mm *per* year (GAPLAN, 1986). In the study area, there are two sandbank formations, named herbaceous sandbank and shrubby sandbank, which occur on the beach shore in mosaics or interspersed with denuded areas.

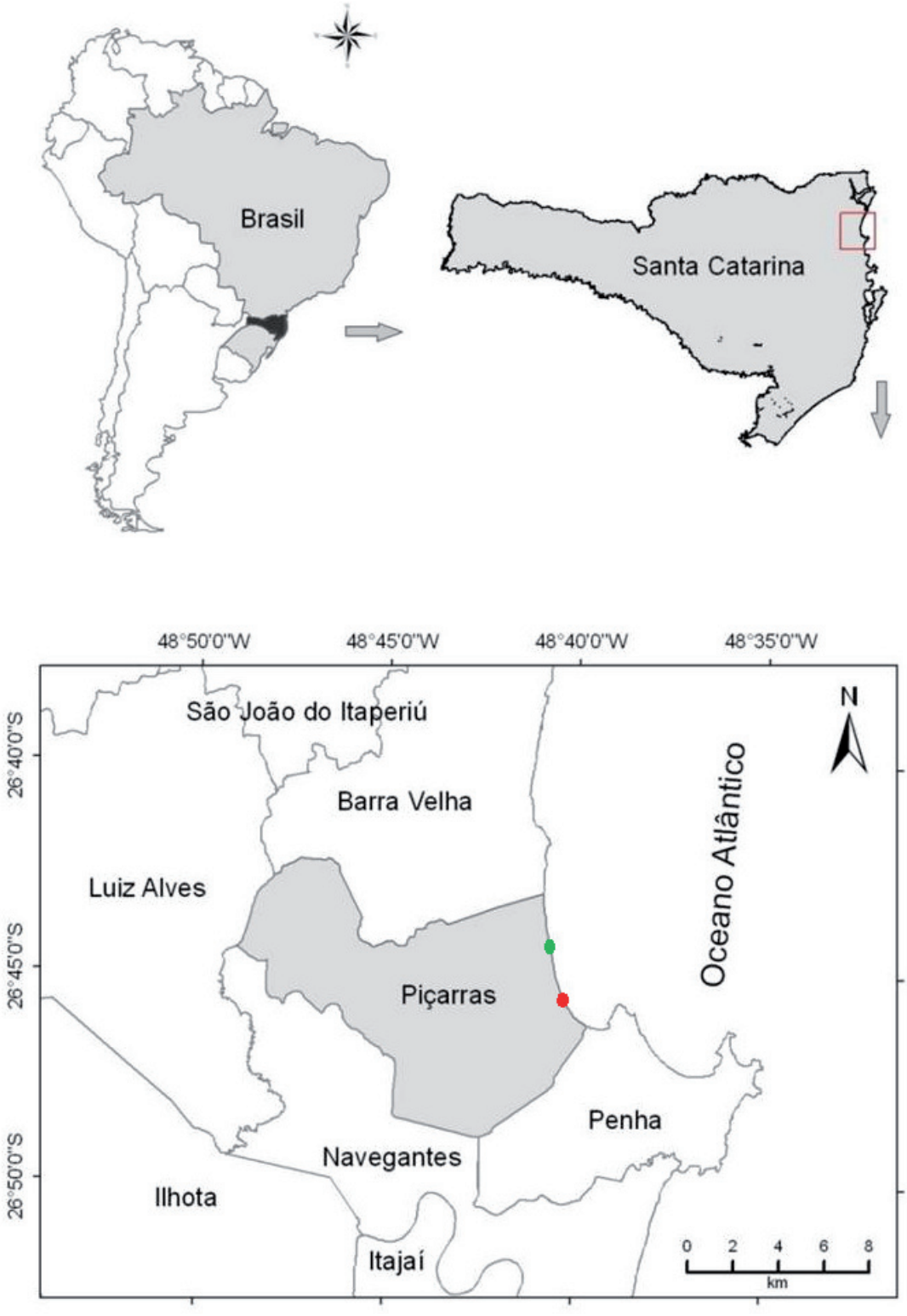

Figure 1 – Study area location in the coastal plain of the city of Balneario Picarras, Santa Catarina. Preserved area (green circle) and degraded area (red circle).

During the floristic survey, plant diversity was mapped by the patrolling method (FILGUEIRAS *et al*., 1994), fertile branches of plants being collected with a manual pruning shears aid. The collected material was processed according to the usual techniques for collecting, preparing and herborizing botanical material, described by IBGE (2012) and Fidalgo & Bononi (1989). The identification was done

by comparative morphology, specialized bibliography and analysis of herbarium specimens deposited in the Herbarium JOI, Department of Biological Sciences, University of Joinville Region – UNIVILLE. The botanical families of the sampled phanerogamous species are based on APGIII classification (APGIII, 2009). The herbarium specimens produced were deposited at Herbarium JOI. The validity of the species names and authors was found in the Species List of the Flora of Brazil (JARDIM BOTÂNICO DO RIO DE JANEIRO, 2014). The characterization of the life forms of the studied species followed the terminology of Raunkiaer and Muller-Dombois (IBGE, 2012).

For the phytosociological survey, the method of plots of 1 x 1m (FELFILI & REZENDE, 2003) was adopted. The inclusion criterion was based on the herbs and subshrubs flora of the dunes. The allocation of the portions was oriented parallel to the shore line by means of a transection extension of 150m. The plots were distributed evenly and far 1m from each other. There were adopted the following phytosociological parameters: absolute and relative coverage and frequency, and coverage value index (MUELLER & ELLENBERG, 1974). The diversity of the flora in the area was calculated by the Shannon diversity index (H') (MAGURRAN, 2013), using the Past software (HAMMER *et al*., 2001).

RESULTS AND DISCUSSION

We sampled 48 species belonging to 44 genera and 22 families (Table 1). The families with the highest species richness were Fabaceae, with ten species (20.83%), Asteraceae with six species (12.5%), Poaceae with four species (8.33%), Amaranthaceae, Convolvulaceae, with three species (12.5%), Calyceraceae, Euphorbiaceae, Polygalaceae and Rubiaceae with two species (16.66%), and the other families with one totaling 29.18% of all samples. The greatest diversity of species occurred in the preserved area of the sandbank, with a total of 48 species instead of eight species recorded in the degraded area.

Table 1 – Families and species of the flora on dunes of the coastal plain of the city of Balneario Piçarras, Santa Catarina.

Family/ Species	Biological form	Preserved area	Degraded area
Amaranthaceae			
Alternanthera littoralis P. Beauv.	herbaceous	x	
Alternanthera maritima (Mart.) A. St-Hil.	herbaceous	x	
Blutaparon portulacoides (A. St.- HIL.) Mears	herbaceous	x	
Gomphrena celosioides Mart.	herbaceous	x	
Anacardiaceae			
Schinus terebinthifolius Raddi.	schrub	x	
Apocynaceae			
Oxypetalum tomentosum Wight H. A.	herbaceous	x	
Araliaceae			
Hydrocotyle bonariensis Lam.	herbaceous	x	x
Asteracea			
Ambrosia sp.	herbaceous	x	x
Baccharis dracunculifolia DC.	schrub	x	
Chaptalia integerrima (Vell.)	herbaceous	x	
Conyza bonariensis (L.)	herbaceous	x	
Facelis retusa (Lam.)	herbaceous	x	
Sphagneticola trilobata (L.)	herbaceous	x	x
Boraginaceae			
Varronia curassavica Jacq.	schrub	x	

Family/ Species	Biological form	Preserved area	Degraded area
Calyceraceae			
Acicarpha spathulata R. Brown	herbaceous	x	
Calycera crassifolia (Miers) Hicken	herbaceous	x	
Commelinaceae			
Commelina villosa C. B.	herbaceous	x	
Convolvulaceae			
Ipomoea imperati (Vahl) Grisebach	herbaceous	x	
Ipomoea pentaphylla (L.) Jacq.	herbaceous	x	
Ipomoea pes-caprae (L.) R. BR.	herbaceous	x	x
Cucurbitaceae			
Cayaponia trifoliata (Cogn.)	herbaceous	x	
Cyperaceae			
Remirea maritima Aubl.	herbaceous	x	
Euphorbiaceae			
Euphorbia hyssopifolia L.	herbaceous	x	
Microstachys corniculata (Vahl)	herbaceous	x	
Fabaceae			
Canavalia rosea (Sw.) D.C.	herbaceous	x	
Centrosema virginianum (L.) Benth	herbaceous	x	
Chamaecrista cytisoides (Collad.)	schrub	x	
Dalbergia ecastaphyllum (L.) Taub.	schrub	x	
Desmodium incanum (Sw.) D.C.	herbaceous	x	
Macroptilium atropurpureum (D.C.)	herbaceous	x	
Senna occidentalis (L.)	schrub	x	
Sophora tomentosa (L.)	schrub	x	
Stylosanthes viscosa Sw.	herbaceous	x	
Zornia latifolia Sm.	herbaceous	x	
Goodeniaceae			
Scaevola plumieri (L.) Vahl	schrub	x	
Myrtaceae			
Myrcia bicarinata (O. Berg) D. Legrand	schrub	x	
Orchidaceae			
Epidendrum fulgens Brong.	herbaceous	x	
Poaceae			
Cenchrus echinatus L.	herbaceous	x	x
Paspalum vaginatum Sw.	herbaceous	x	x
Spartina ciliata Brogniart	herbaceous	x	x
Stenotaphrum secundatum (Walter)	herbaceous	x	
Polygalaceae			
Polygala cyparissias St.-Hil. & Moq	herbaceous	x	
Polygala paniculata L.	herbaceous	x	
Rubiaceae			
Diodella radula (Willd.)	herbaceous	x	
Diodia setigera DC.	herbaceous	x	

Family/ Species	Biological form	Preserved area	Degraded area
Solanaceae			
Solanum subulatum C.H. Wright	herbaceous	x	
Turneraceae			
Turnera subulata L.	herbaceous	x	
Verbenaceae			
Lantana camara L.	schrub	x	

Comparing the floristic results obtained in this study with other surveys conducted in the coastal portion of Santa Catarina, it is clear that the richness of the sandbank on dunes in *Balneario Piçarras* is predominantly low, except when compared to two areas of sandbank in the cities of Florianópolis and Garopaba (Table 2).

Table 2 – Comparison of the specie's richness with other studies done in dune habitats in the state of Santa Catarina, Brazil.

Study	City	Species
This work	Balneário Piçarras	48
Bresolin (1979)	Florianópolis	22
Cordazzo & Costa (1989)	Garopaba	31
Danilevicz *et al*. (1990)	Garopaba	75
Castellani *et al*. (1995)	Florianópolis	61
Daniel (2006)	Araranguá	124
Guimarães (2006)	Florianópolis	104
Klein *et al*. (2007)	Araranguá	60
Korte *et al*. (2013)	Araranguá, Florianópolis, Palhoça e São Francisco do Sul	225
Melo Júnior & Boeger (2015)	São Francisco do Sul	77

The diversity of identified species was H' = 3.9 in the preserved area and H' = 2.1 in the degraded area. Studies done in other *restingas* over dunes in the state of Santa Catarina showed H' = 2.89 in São Francisco do Sul (MELO JR. & BOEGER, 2015), H' = 3.25 in Araranguá (KLEIN *et al*., 2007) and H' = 2.71 Florianopolis (KORTE *et al*., 2013). Even with a lower species richness than those obtained in the cited works, the Shannon index shows up higher, quite possibly by the fact that it was generated by a matrix of presence/ absence and not abundance, so it is necessary to consider such information by the floristic list produced for each studied area.

The botanical families Fabaceae and Asteraceae were those with the highest species richness, which corroborates the results of the survey done in an herbaceous sandbank in Araranguá (SC) (DANIEL, 2006). The representativity of the families in this study is in accordance with what was found for herbaceous sandbanks in southern Brazil (KLEIN *et al*., 2007), where there is a predominance of Asteraceae, Poaceae, Cyperaceae and Fabaceae in species richness, varying only the order of importance of each family in each studied sandbank (SOUZA *et al*., 1986; DANILEVICZ *et al*., 1990; DANIEL, 2006; GUIMARÃES, 2006).

During the phytosociological survey which was carried out in a total of 100 plots, with 50 plots in each area (preserved and degraded) of the studied sandbank. The sample sufficiency was achieved by stabilizing the species-area curve. In the preserved area, there were sampled 16 species, distributed in 15 genera belonging to 11 families (Table 3). The species that had higher coverage amounts were: *Canavalia rosea* (26.21%), *Remirea maritima* (24.91%), *Stenotaphrum secundatum* (22%), *Spartina ciliata* (16.62%) and *Acicarpha spathulata* (14.71%), which stood out in the community structure. In

the degraded area there were sampled eight species of eight genera and five families (Table 4). The species that showed the most important coverage, representing 54.70% of the total sampled area, were: *Spartina ciliata* (46.81%), *Ipomoea pes-caprae* (33.90%) and *Sphagneticola trilobata* (28.70%).

Table 3 – Phytosociologic parameters for the sampled species at the preserved área, in terms of decrease of IVC (coverage importance value). Legend: absolute frequency (FAi); and relative frequency (FRi); absolute coverage (CAi) and relative coverage (CRi).

Family	Species	FAi	FRi	CAi	CRi	IVC
Fabaceae	*Canavalia rosea*	96	14.04	20.47	12.17	26.21
Cyperacea	*Remirea maritima*	100	14.62	17.3	10.29	24.91
Poaceae	*Stenotaphrum secundatum*	70	10.23	19.79	11.77	22.00
Poaceae	*Spartina ciliata*	90	13.16	5.83	3.47	16.62
Calyceraceae	*Acicarpha spathulata*	4	0.58	23.75	14.12	14.71
Araliaceae	*Hydrocotyle bonariensis*	74	10.82	5.34	3.18	13.99
Convolvulacae	*Ipomoea pes-caprae*	62	9.06	7.98	4.75	13.81
Goodeniaceae	*Scaevola plumieri*	10	1.46	20	11.89	13.35
Amaranthaceae	*Alternanthera littoralis*	62	9.06	3.95	2.35	11.41
Convolvulacae	*Ipomoea imperati*	60	8.77	3.22	1.91	10.69
Poligalaceae	*Blutaparon portulacoides*	14	2.05	13.21	7.86	9.90
Asteraceae	*Ambrosia sp*	8	1.17	12.5	7.43	8.60
Fabaceae	*Desmodium incanum*	22	3.22	5.45	3.24	6.46
Poaceae	*Paspalum vaginatum*	8	1.17	4.38	2.6	3.77
Poligalaceae	*Polygala cyparissias*	2	0.29	2.5	1.49	1.78
Asteraceae	*Facelis retusa*	2	0.29	2.5	1.49	1.78

Table 4 – Phytosociologic parameters for the sampled species in the degraded rea in terms of decrease of IVC (coverage importance value). Legend: absolute frequency (FAi); and relative frequency (FRi); absolute coverage (CAi) and relative coverage (CRi).

Family	Species	FAi	Fri	Cai	Cri	IVC
Poaceae	*Spartina ciliata*	40	21.51	25.5	25.31	46.81
convolvulaceae	*Ipomoea pes-caprae*	46	24.73	9.24	9.17	33.90
Asteraceae	*Sphagneticola trilobata*	10	5.38	23.5	23.32	28.70
Poaceae	*Paspalum vaginatum*	20	10.75	14.5	14.39	25.14
Poaceae	*Cenchrus echinatus*	22	11.83	9.32	9.25	21.08
Rubiaceae	*Diodella radula*	26	13.98	5.38	5.34	19.32
Araliaceae	*Hydrocotyle bonariensis*	18	9.68	3.33	3.30	12.98
Asteraceae	*Ambrosia* sp	4	2.15	10	9.92	12.07

Among the dominant species in the preserved area, *Canavalia rosea* (Fabaceae) is a creeping plant with dense foliage. It has short root taproot, shallow, which at 10 cm takes horizontal direction and reaches up to 3 meters long. It is an important species in the transition zone between the incipient dune of *Blutaparon portulacoides* and the established dunes of *Panicum racemosum* or *Spartina ciliata.* With its creeping form and vigorous growth, it overlies densely the substrate and retains sand (CORDAZZO *et al*., 2006).

Remirea maritima (Cyperaceae) is a perennial herb, with a little root system branched or unbranched that reaches the depth of 10 to 30 cm. It has a slightly pronounced rest period, in April and August. Its main characteristic is the dense network formed by its rhizomes, at a depth of about 30 cm, thus higher than that of most of the plants of the same habit. Where the network is deeper, the stems can pierce layers of 50 cm to reach the surface. The ability of the plants to fix sand is not very big. Incipient dunes that form in the calm zone of these plants are always small (CORDAZZO *et al*., 2006).

Stenotaphrum secundatum (Poaceae) is a species of grass very well suited to the common hot weather in the areas of sandbank (PIMENTA, 2003).

Spartina ciliata (Poaceae) is considered one of the fixing species of coastal dunes. It is a perennial plant, robust, caespitose, with a short rhizome, which are born many more or less branched aerial stems at the bottom, with about 0.30 to 2 meters height. It is a plant characteristic of coastal environment, heliophytic, xerophytic, halophytic, which can be found in several types of habitat in the coastal dune system. Pioneer populations establish from seed (CORDAZZO *et al*., 2006).

Acicarpha spathulata (Calyceraceae), a herbaceous plant, of light green color, have spathuliform glabrous leaves. It grows singly or in groups of up to one meter in diameter, formed by many plants in various stages of development. It is a species heliophytic and drought resistant, characteristic of dunes fixed by *Panicum racemosum* and *Spartina ciliata*, where the substrate is stable. Because of its root system not very deep but efficient for larger groups of *Acicarpha* plants and also because of the dense coverage formed by superficial branches, the species has considerable importance for the formation of small dunes and for fixing existing dunes (CORDAZZO *et al*., 2006).

Considering the most representative species in degraded areas, *Ipomoea pes-caprae* (Convolvulaceae) is a creeping plant, evergreen, fast growing, which can colonize large areas that are devoid of vegetation. The species is well adapted to unstable substrate, even on beaches with active sand movement due to wind and wave action. It is considered of great importance in fixing the sand, especially in the transition zone between the vegetation of embryonic and frontal dunes. Its long and strong stems cover the ground for extensive areas. It forms a large number of short stems that bind the sand and, behind the plants, small dunes are formed, the species having thus a potential use in sand fixation dunes in coastal dunes (CORDAZZO *et al*., 2006).

Sphagneticola trilobata (Asteraceae), despite appearing as a dominant species which organizes the structure of the sandbank community in question, is not a typical plant of this vegetation. Its presence, covering large portions of land in the post-beach sandbank environment, may indicate that the site is strongly impacted and that the characteristic vegetation of the sandbank formation was suppressed by human actions (MOREIRA & BRAGANÇA, 2011).

All of the information that morphologically characterizes the dominant and typical species of dune environment, described above, reflects the high control potential of the erosive action of the wind and, therefore, the geomorphological stabilization of post-beach environment. This also means controlling the mobility of sandy sediments which allows the installation of other constituent species of the herbaceous formation of sandbanks.

Throughout the study area, three exotic species were identified, belonging to three genera and three families (*Thunbergia alata* Sims - Acanthaceae, *Peumus boldus* Molina - Monimiaceae and *Malvaviscus arboreus* Cav. - Malvaceae), which were disregarded in the phytosociological record. *T. alata* is a herbaceous ruderal species, native to tropical areas of East Africa (MOREIRA & BRAGANÇA, 2011); *P. boldus* is native to central and southern Chile, where it occurs abundantly (RUIZ *et al*., 2010) and *M. arboreus* is a woody shrub, densely branched, originating in Mexico and northern South America (LORENZI & SOUZA, 2001).The major problem generated by invasive plants is that, once installed, they compete for resources effectively and limit the distribution of native species, gradually replacing them. The native species eventually disappear, as the rest of the environment is occupied (ZILLER, 2001).

CONCLUSION

For the ecological restoration of the degraded area of *Balneario Picarras* sandbank, the species with the highest importance for coverage in the preserved part (*Canavalia rosea, Remirea maritima, Stenotaphrum secundatum, Spartina ciliata* and *Acicarpha spathulata*) should be chosen as the species to be used for revegetation through environmental restoration techniques.

As they responded to 52.22% of the coverage value of the entire held sample, they are considered pioneer species, community organizers, who hold the best performance to explore the available environmental resources in the limiting environment offered by the sandbank (MELO JR., 2015). Allied to this, their way of life, represented by the formation of stolonipherous and rhizomatous stems, displays a high fixing dune potential and an environment stabilizer, before the erosion of the coast (CORDAZZO *et al.*, 2006).

Such species should be placed in the environment by planting techniques and direct planting of nursey seedlings, in addition to the transposition of seedlings of adjacent areas to the area to be recovered (ZANELLA *et al.*, 2010). Zamith & Scarano (2006) point out that, for the successful restoration of sandbank areas, it is necessary to remove the exotic species before the planting of native plant seedlings. The authors suggest that direct planting of seedlings is the best strategy for this environment, given that the establishment of seedlings from seeds is very difficult in the sandy soil of the sandbank, which is poor in nutrients and with high insolation and low water retention.

However many restoration projects promote the seed supply as well as the planting of seedlings (MIRANDA *et al.*, 1997; BECHARA, 2003), and these planting of seedlings may derive from seed or stolon fragments and rhizome of species that have such structures (FREIRE, 1983; SCHERER-WIDMER, 2001; GOMES-NETO *et al.*, 2004).

In addition to the techniques mentioned by the above authors, it is of utmost importance that, during the environmental recovery process, there is a follow-up by a professional of the environmental area to monitor the seedlings in the first months after implantation, to watch for their irrigation as well as for the protection of the area, by building a fence, so that there is not the trampling of plants (ZANELLA *et al*., 2010).

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