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RELATIONSHIP BETWEEN THE SAND SPIT GEOMORPHOLOGY AND RESTINGA VEGETATION IN SÃO FRANCISCO DO SUL ISLAND, SOUTH REGION OF BRAZIL

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ABSTRACT

The ocean sand beaches prove to be relevant transitional systems of the coastal zone, highly dynamic and sensitive by virtue of the movement of sediments transported through the constant effects of the waves, coastal currents, tides and winds. The sandspits of Capri beach, São Francisco do Sul, southern Brazil, are characterized by their high dynamics and close correlation with the *resting* vegetation. The purpose of this work is to analyze the morphology of sandspit and its interaction with the resting vegetation in the structure of the landscape. The herbaceous flora was structurally characterized by means of the phytosociological method, while the geomorphology was characterized by the obtaining of historical and oceanographic morphometric parameters. The analysis of geomorphological and vegetative interaction was carried out through PCA and cluster analysis. The geomorphological mapping identified six different geomorphological units when analyzing variables related to age, width, altitude, sediment volume and dominant geomorphological process, finding a great coastline variation during the period under analysis (1957 to 2016). A total of 18 species, 11 families and a total of 323 individuals were registered in six different geomorphological units. The species *Ipomoea pes-caprae* and *Spartina ciliata* were found in all geomorphological units, characterizing their stability in the place. Statistical analysis of interaction between the geomorphological and vegetative variables demosntrated the formation of two groups of the sandspits.

INTRODUCTION

The ocean sand beaches prove to be relevant transitional systems of the coastal zone, highly dynamic and sensitive by virtue of the movement of sediments transported through the constant effects of the waves, coastal currents, tides and winds (Calliari *et al*., 2003), this being subject to erosion or deposicional process. The sandspit definition is used to reefer to a sandy relief characteristic, formed by a series of coastal strands crests connected to the mainland or to an island by one of the edges (Suguio, 1992; Diehl, 1997). The knowledge about the morphodynamic behavior of a specific beach allows the spatial-temporal monitoring of deposition or erosion cycles. Such assessment considerably increases the level of success of various activities related to coastal zone management (Carter, 1988).

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Therefore, the morphodynamics study has proved to be very efficient in the management and solution of environmental problems related to sandy beaches (Komar, 1976; Calliari *et al*., 2003; Araújo, 2008). A peculiar type of vegetation develops in association with these sandy deposits, which is mainly conditioned to the oligotrophic nature of the soil (Melo Jr. & Boeger, 2015). Overall, *Restinga* is represented by a floristic-communities mosaic with strongly defined species and structure composition, whose diversity is growing in the sea-continent direction due to the mitigation of environmental conditions (Melo Jr. & Boeger, 2015). The sandy sediments of the post-beach plot are occupied by a pioneering herbarium-herbaceous community highly adapted to the sediment mobility. This environment is often moistened by the action of waves and by sea spray, with restrictions to the installation and growth of plant community (Scarano, 2002). It stands out along the Brazilian coast because it is covered by plant communities that are both characteristic and peculiar at each part of the coast along the latitudinal gradient (Lacerda & Araujo, 1987). This vegetation, under constant stress due to active abiotic factors, is ecological relevant in several processes of the ecosystem dynamics, such as sediment storage and transportation, nutrient mineralization and recycling, maintenance of biodiversity and resources, nesting area for small mammals and birds, bird resources, among others (Defeo *et al*., 2009). Menezes & Araújo (1999) mentioned that the distribution of plant species is directly linked to the processes determining the beach profile, such as wave effects on the coastline, post-beach width, sediment deposition and granulometry. An expansion of vegetation is expected in periods with increased sediments and a decrease in vegetation coverage is expected in erosion periods (Castellani & Santos, 2000; Hesp, 2002; Peixoto, 2005; Miot Da Siva, 2006). In this sense, it is highly important to improve the management of the coastal zone, which shall start to consider the historical analysis of the beach morphodynamics and the characteristics of the vegetation structure in order to provide the correct use and conservation of coastal environments (Horn Filho, 2006; Calliari *et al*., 2003). Given the above, the present work aims to identify the morphodynamic behavior of the sandspit and the interrelationship with the development of *Restinga* vegetation in Capri beach, São Francisco do Sul, State of Santa Catarina, Brazil.

MATERIALS AND METHODS

Study Area

The island of San Francisco has a coastline of 263.61km with the occurrence of distinct hydrodynamic environments, with exposed and semi-sheltered beaches and tidal plains with broad occurrence of mangroves and salt marshes (Vieira, 2015). The northern coast of the state of Santa Catarina and the Capri beach are under the control of a microtidal regime (amplitude <2 m), mixed with the prominent semi-diurnal regime, with an average amplitude of 0.84m, maximum of 1.9m and minimum of 0.2 m during spring tide periods (Truccolo & Schettini, 1999). Abreu (2011) identified that the wave break range is < 0.5 m and classified the beach as low energy (Jackson *et al*., 2002).

The long shore current predominant in the region of São Francisco do Sul island has south-north orientation. Such current orientation was found in 70% of the measurements performed, against 25% of occurrences to the south (Abreu, 2011). Rainfall in the region is 2,500mm / year. The most dry months of the year are August and June, with 92.2mm and 96.4mm; while the wettest months are February and January, with 281mm and 2481 mm, respectively (Pandolfo *et al*., 2002; Mello *et al*., 2015, 2016). Capri beach is located in the north of São Francisco do Sul island (Figure 1). It is 3.9km long, and represents a system of sandspits that isolated lagoons in the back barrier (Vieira, 2015). The environment is composed of fine sand, particular to low-energy environments, with mixed characteristics, under dominating marine and estuarine influence (Horn Filho, 1997; Abreu, 2011)

Obtaining geomorphological data

Aerial photos and high-definition satellite images from1957, 1978, 2003, 2011, 2012 and 2016 were used for the evolution and morphological analysis of Capri beach, in order to rebuild the relative position of the coastline of the beach and to estimate the ages of the sandspit. The Digital Elevation Model (DEM) was used in a scale of 1:10,000 throughout the area studied.

The hydrodynamic and sedimentlogical characteristics of Capri beach is obtained in the surveys of Abreu (2011) and Haupt (2011). At the end of all the steps described above, it was possible to obtain the following information: a) Coastline morphology for the years 1937, 1957, 1978, 2003, 2011, 2012, 2016, and average age, b) Morphometry of the sandspits: Total area, maximum, minimum and average width, maximum, minimum and average altitude, altimetric amplitude, sediment volume, ratio volume/area, c) hydrodynamics: Type of hydrodynamic exposure by wave effect, type of influence of hydrodynamic processes. All cartographic information were handled in a Geographic Information System (GIS) using ArcGIS 10.2, UTM projection and SIRGAS2000 datum.

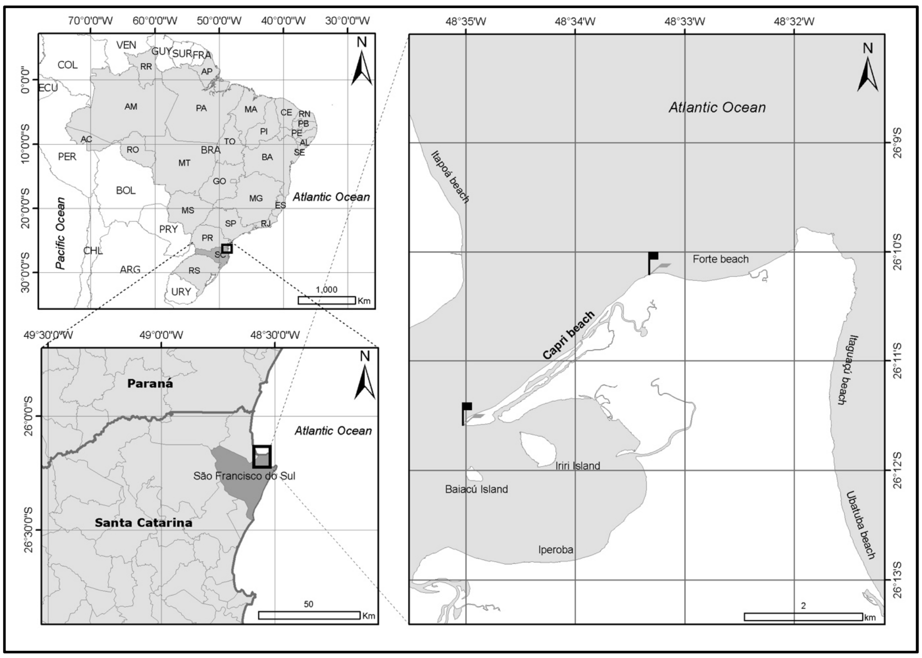

Figure 1. Location of the Capri Beach in São Francisco do Sul, Santa Catarina, Brazil

Figure 2. Geomorphological units on Capri beach, São Francisco do Sul - SC

Table 1. Morphometric parameters of Capri Beach, São Francisco do Sul- SC

Geomorphological unit	Area (m^2)	Altitud (m)	Sand volume (m^3)	Ratio volume / area(m^3/m^2)	Mean width	Mean age
Unit 1	28.011	2,42	20.745,72	0,74	13,55	4,3
Unit 2	7.146	2,03	8.392,92	1,17	16,84	9,0
Unit 3	29.680	2,78	40.784,57	1,37	16,77	20,5
Unit4	31.650	2,55	16.669,11	0,52	12,8	18,7
Unit5	18.597	2,71	32.056,90	1,72	24,64	55,0
Unit6	93.398	3,81	177.372,60	1,89	28,75	28,5

Restinga Vegetation Data collection

A phytosociological survey of the vegetation was performed using the 1x1m plots method (Felfili *et al*., 2011). The plots were distributed perpendicular to the longitudinal axis of the sandspit in all the geomorphological units in the sample area.
Were allocated 25 plots in each geomorphological unit of the sandspit, totaling 150 sample plots. The absolute and the relative coverage, the absolute and relative frequency, and the coverage amount index were adopted as phytosociological parameters (Munhoz & Araújo, 2011).

The coverage of each species was visually estimated according to the scale proposed by Causton (1988), containing six coverage classes evaluating, in percentage, the projection of the aerial part of the plant on the plot surface. This scale is shown below: 1 = up to 5% plot coverage, 2 = 5.1 - 15% plot coverage, 3 = 15.1 - 25% plot coverage, 4 = 25.1 - 50 % plot coverage, 5 = 50.1 - 75% plot coverage, 6 = 75.1-100% plot coverage. The behavior of the sampled species was registered and their identities recognized. The samples collected were handled according to the usual techniques applicable to botanical material (Fidalgo & Bononi, 1989). The definition of species was based on species lists of the local *Restinga* flora (Melo Jr. & Boeger, 2015) and confirmed through the List of Brazilian Flora (Brazilian Flora, 2017). The species list fulfills the order by APG IV (2016). Species names and the authors thereof were confirmed in the list of Brazilian flora species (Forzza *et al*., 2010).

Statistical Data Analysis

Data was analyzed using two statistical techniques: Cluster Analysis and Principal Components Analysis (PCA). The 28 variables used have different measurement scales and were standardized, so that all variables have zero average and single variance, which is achieved by transforming the data into "z" values (Legendre & Legendre, 1998; Valentin, 2000). The Cluster Analysis aimed to evaluate the similarities in the hierarchical grouping of objects (Q mode), using the Euclidean distance square coefficient, the grouping strategy adopted was the minimum variance (Ward's method). In this study, we analyze six geomorphological units described by 28 variables, which results in a universe of 168 cases to be analyzed. With the use of PCA, the result is a reduced system of coordinates (axes), which provides better view of the information on geomorphological and vegetative similarities. In the PCA analysis, the first four eigenvectors (axes) explaining 92.31% of the point cloud dispersion were adopted according to the Jolliffe rule (Jolliffe, 2002).

RESULTS

Geomorphology

Capri beach has gone through intense morphological changes from 1957 to 2016, due to the development of successive sandspits.

Table 2. Species sampled in the geomorphological units and their phytosociological parameters: NPi - number of plots occurred in the species *i*; FAi - absolute frequency; FRi - relative frequency; CAi - absolute coverage; CRi - relative coverage and CVI - coverage value index

Geomorphological unit	Family	Species	NPi	FAi (%)	FRi (%)	CAi (%)	CRi (%)	CVI
Unit 1	Poaceae	*Spartina ciliata*	20	80	31,25	203,50	26,55	57,80
	Convolvulaceae	*Ipomoea pes-caprae*	18	72	28,13	181,11	23,63	51,75
	Apiaceae	*Hydrocotyle bonariensis*	9	36	14,06	139,72	18,23	32,29
	Asteraceae	*Sphagneticola trilobata*	7	28	10,94	108,93	14,21	25,15
	Fabaceae	*Desmodium incanum*	3	12	4,69	54,17	7,07	11,75
	Rubiaceae	*Diodella radula*	3	12	4,69	36,67	4,78	9,47
	Poaceae	*Eragrostis trichocolea*	2	8	3,13	20,00	2,61	5,73
	Fabaceae	*Chamaecrista flexuosa*	1	4	1,56	20,00	2,61	4,17
	Cyperaceae	*Remirea maritima*	1	4	1,56	2,50	0,33	1,89
Unit 2	Convolvulaceae	*Ipomoea pes-caprae*	19	76	33,93	388,03	36,58	70,51
	Poaceae	*Paspalum vaginatum*	18	72	32,14	330,56	31,17	63,31
	Amaranthaceae	*Blutaparon portulacoides*	13	52	23,21	261,54	24,66	47,87
	Apiaceae	*Hydrocotyle bonariensis*	5	20	8,93	70,50	6,65	15,58
	Poaceae	*Spartina ciliata*	1	4	1,79	10,00	0,94	2,73
Unit 3	Fabaceae	*Vigna* sp.	11	44,00	26,19	285,91	29,10	55,29
	Fabaceae	*Canavalia rosea*	8	32,00	19,05	193,75	19,72	38,77
	Poaceae	*Paspalum vaginatum*	7	28,00	16,67	145,36	14,79	31,46
	Convolvulaceae	*Ipomoea pes-caprae*	6	24,00	14,29	110,83	11,28	25,57
	Amaranthaceae	*Blutaparon portulacoides*	3	12,00	7,14	106,67	10,86	18,00
	Aizoaceae	*Sesuvium portulacastrum*	4	16,00	9,52	72,50	7,38	16,90
	Asteraceae	*Ambrosia* sp.	1	4,00	2,38	37,50	3,82	6,20
	Calyceraceae	*Acicarpha spathulata*	1	4,00	2,38	20,00	2,04	4,42
	Poaceae	*Spartina ciliata*	1	4,00	2,38	10,00	1,02	3,40
Unit 4	Fabaceae	*Canavalia rosea*	19	76	33,93	301,05	35,30	69,23
	Poaceae	*Spartina ciliata*	10	40	17,86	141,00	16,53	34,39
	Asteraceae	*Ambrosia* sp.	7	28	12,50	120,36	14,11	26,61
	Fabaceae	*Vigna* sp.	5	20	8,93	85,00	9,97	18,90
	Apiaceae	*Hydrocotyle bonariensis*	3	12	5,36	26,67	3,13	8,48
	Poaceae	*Paspalum vaginatum*	2	8	3,57	30,00	3,52	7,09
	Polygalaceae	*Polygala cyparissias*	2	8	3,57	30,00	3,52	7,09
	Amaranthaceae	*Blutaparon portulacoides*	2	8	3,57	28,75	3,37	6,94
	Aizoaceae	*Sesuvium portulacastrum*	2	8	3,57	20,00	2,35	5,92
	Amaranthaceae	*Alternanthera maritima*	1	4	1,79	20,00	2,35	4,13
	Convolvulaceae	*Ipomoea pes-caprae*	1	4	1,79	20,00	2,35	4,13
	Poaceae	*Eragrostis trichocolea*	1	4	1,79	20,00	2,35	4,13
	Calyceraceae	*Acicarpha spathulata*	1	4	1,79	10,00	1,17	2,96
Unit 5	Fabaceae	*Canavalia rosea*	15	60	34,09	248,83	30,75	64,84
	Poaceae	*Paspalum vaginatum*	11	44	25,00	189,32	23,39	48,39
	Poaceae	*Spartina ciliata*	10	40	22,73	207,00	25,58	48,30
	Convolvulaceae	*Ipomoea pes-caprae*	3	12	6,82	64,17	7,93	14,75
	Apiaceae	*Hydrocotyle bonariensis*	3	12	6,82	60,00	7,41	14,23
	Amaranthaceae	*Blutaparon portulacoides*	1	4	2,27	20,00	2,47	4,74
	Fabaceae	*Vigna* sp.	1	4	2,27	20,00	2,47	4,74
Unit 6	Convolvulaceae	*Ipomoea pes-caprae*	22	88	35,48	433,41	33,17	68,66
	Poaceae	*Spartina ciliata*	16	64	25,81	383,75	29,37	55,18
	Apiaceae	*Hydrocotyle bonariensis*	13	52	20,97	264,04	20,21	41,18
	Poaceae	*Paspalum vaginatum*	7	28	11,29	147,86	11,32	22,61
	Amaranthaceae	*Blutaparon portulacoides*	1	4	1,61	37,50	2,87	4,48
	Fabaceae	*Canavalia rosea*	1	4	1,61	20,00	1,53	3,14
	Fabaceae	*Vigna* sp.	1	4	1,61	10,00	0,77	2,38
	Polygalaceae	*Polygala cyparissias*	1	4	1,61	10,00	0,77	2,38

Several ruptures of the sandy barrier and the development of an urbanized area in this period were also observed. Based on the morphology of the coast line, the age range, the altitude, the width and the level of exposure to wave effects it was possible to outline six geomorphological units in the sandspits (Figure 2). The morphometric parameters for each geomorphological unit are shown in Table 1 below. The geomorphological unit 1 has an average age of 4.3 years, altitude of 2.42m, area of 28,011m^2, sediment volume of 20,745m^3, average width of 13.55m and volume/area ratio of 0.74m^3/m^2 and, therefore, it was classified as exposed, dominated by waves and influenced by tides. The geomorphological unit 2 has average age of 9 years, altitude of 2.03m, area of 7.146 m², average width of 16.84m, sediment volume of 8.392m³, and, therefore, it was classified as exposed, dominated by waves and influenced by tides. The geomorphological unit 3 has average age of 20.5 years, altitude of 2.78m, area of 29.680 m^2, average width of 16.77m, sediment volume of 40,478.57m^3 and, therefore, it was classified as sheltered, dominated by waves. The geomorphological unit 4 has average age of 18.7 years, altitude of 2.55m, area of 31,650m^2, average width of 12.8m, sediment volume of 16,669.11m^3 and, therefore, it was classified as sheltered, dominated by tides. The geomorphological unit 5 has average age of 55 years, altitude of 2.71m, area of 18,597m², average width of 24.64m, sediment volume of 32,056.90m³ and, therefore, it was classified as dominated by wind. The geomorphological unit 6 has average age of 28.5 years, altitude of 3.81m, area of 93.398m², average width of 28.75m, sediment volume of 177,372.60m³ and, therefore, it was classified as dominated by wind and under influence of tides when in contact with the coastline.

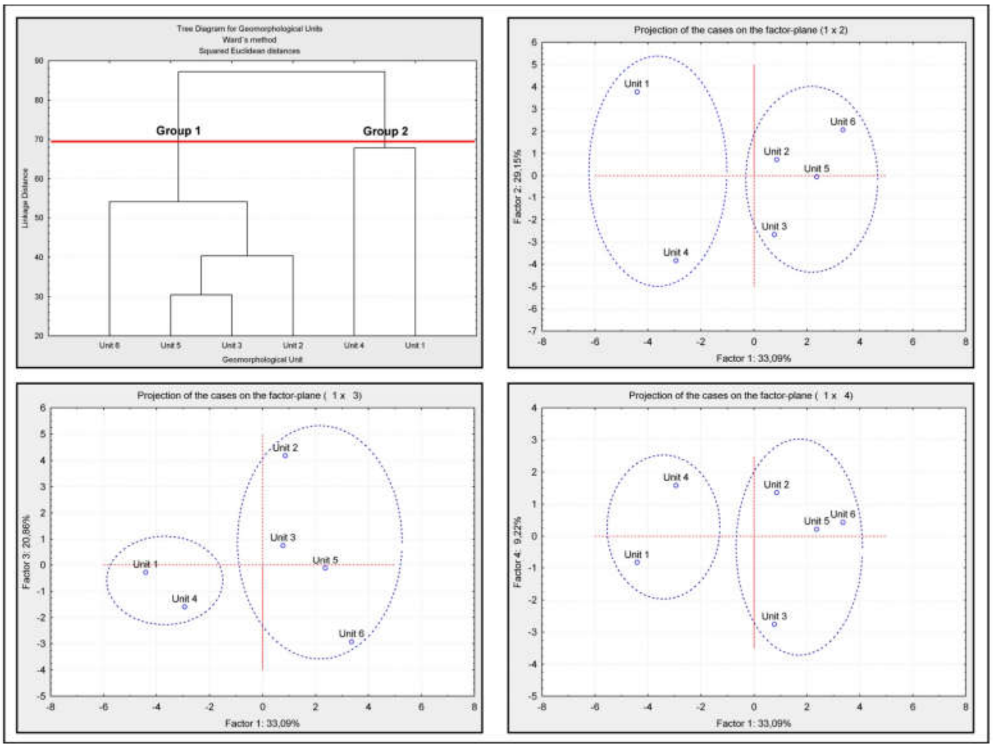

Figure 3.Cluster analysis and Principal Components Analysis (PCA) with the formation of two sample groups

Table 3. Sectorization of sandspits and their morphometric and phytosociological parameters: NPi - number of plots with occurrence of the species i; FAi – average absolute frequency; FRi – average relative frequency; CAi – average absolute coverage; CRi - average relative coverage; Cv - Coefficient of variation (%)

Group	Area	Altitud average	Sand volume	Ratio volume / area	Width mean	Idade mean	NPi	FAi	FRi	CAi	CRi
	(m^2)	(m)	(m^3)	(m^3/m^2)	(m)	(anos)	(n)	(%)	(%)	(%)	(%)
1	37.205,25 cv=103%	2,83 cv=25%	64.651,75 cv=118%	1,54 cv=21%	21,75 cv=27%	28,25 cv=69%	204	28,14 cv=91%	13,79 cv=85%	143,41 cv=91%	13,79 cv=86%
2	29.830,50 cv=8%	2,49 cv=3%	18.707,42 cv=15%	0,63 cv=24%	13,18 cv=4%	11,5 cv=88%	120	21,82 cv=112%	9,09 cv=110%	73,61 cv=106%	9,09 cv=106%

Vegetation Coverage

The phytosociological survey demonstrated 323 vegetal specimens occurred in the six geomorphological units, which were distributed in 18 species, 18 genders and 11 families. The families with the highest number of species were: Fabaceae (4), Poaceae (3), Amaranthaceae and Asteraceae (2). The geomorphological unit 4 had the highest specific diversity, with a total of 13 species, followed by units 1 and 3, with 9 species each. The species *Ipomoea pes-caprae* and *Spartina ciliata* were found in all geomorphological units. Table 2 comprises the quantitative parameters for the species sampled, listed according to the geomorphological units. In geomorphological unit 1, the species with the highest absolute frequency (80%) was *Spartina ciliata*, with a coverage value index (CVI) of 57.80. The second species with the highest CVI (51.75) was *Ipomoea pes-caprae*, with frequency of 72%. The geomorphological unit 2 had absolute frequency value of (76%) for the species *Ipomoea pes-caprae*, with a coverage value index (CVI) of 70.51, highlighted given its high relative coverage (36.58%). The second species with the highest CVI (63,31) was *Paspalum vaginatum* with 72% frequency. In the geomorphology unit 3, the absolute frequency value of (44%) refers to *Vigna* sp., with coverage value index (CVI) of 55.29. The second species with the highest CVI (38.77) was *Canavalia rosea* with 32% frequency. In unit 4, the absolute frequency value was (76%) for *Canavalia rosea* species with coverage value index (CVI) of 69.23. The second species with the highest CVI (34.39) was Spartina ciliata, with a frequency of 40%. In unit 5, the absolute frequency value was (60%) for the Canavalia rosea species with a coverage value index (CVI) of 64.84. In unit 4, the absolute frequency value is (76%) for *Canavalia rosea* species, with coverage value index (CVI) of 69.23.

The second species with the highest CVI (34.39) refers to *Spartina ciliata*, with 40% frequency. In unit 5, the absolute frequency value is (60%) for *Canavalia rosea* species, with coverage value index (CVI) of 64.84. The second species with the highest CVI (48.39) is *Paspalum vaginatum,* with 44% frequency. The geomorphological unit 6, where the absolute frequency value is (88%) for *Ipomoea pes-caprae* species, with coverage value index (CVI) of 68.66. The second species with the highest CVI (55.18) was *Spartina ciliata*, with 64% frequency. The occurrence of the families in this study consists with the occurrence observed in areas of herbaceous *restinga,* in southern Brazil, where it is observed the predominance of families of Asteraceae, Cyperaceae, Fabaceae and Poaceae, varying only the order of importance for different locations.

(Souza *et al*., 1986; Danilevicz *et al*., 1990). On the southern coast of the state of Santa Catarina predominate soils formed by quartz sands, originated from marine, lagoon and wind sediments (Klein, 1984). According to this author, these are deep, sandy, over-drained soils with predominance of *Ipomoea pes*-caprae, *Senecio crassiflorus* and *Hydrocotyle bonarienses.* According to what we can observe along the geomorphological unit 1, the species *Spartina ciliata* was evidently predominant, occurring in areas near the sea, and found together with the species *Ipomoea pes-caprae*. Due to their presence in all geomorphological units, these species presented the highest values for the coverage index (CVI). The species *Chamaecrista flexuosa* and *Remirea maritima* were found only in this geomorphological unit, being characterized as low-frequency species.

The geomorphological units 2 and 3 occurring in humid depressions between the crest, also known as "herbaceous marshes" (Araújo & Henriques, 1984), presented psamophilic vegetation of the humid lowlands, represented by the species *Ipomoea pes-caprae*, *Paspalum vaginatum*, *Blutaparon portulacoides*, *Vigna* Sp. and *Canavalia rosea*. The species *Paspalum vaginatum* was the third most abundant among all geomorphological units under study. In the geomorphological unit 4, there was predominance of *Canavalia rosea* species, with greater coverage index (69.23), followed by *Spartina ciliata* (34,39) and *Ambrosia* sp. (26,61). The species *Alternanthera maritima*, *Ipomoea pes-caprae*, *Eragrostis trichocolea* and *Acicarpha spathulata* were found, but with low frequency, represented only by a single individual. The geomorphological unit 5 was characterized by the occurrence of the species *Canavalia rosea*, *Paspalum vaginatum*, *Spartina ciliata*, *Ipomoea pes-caprae*, *Hydrocotyle bonariensis*, *Blutaparon portulacoides* and *Vigna* sp. Among which, *Canavalia rosea* presented a higher coverage value index (64.84), given the high abundance in this unit. The geomorphological unit 6 was characterized by the species *Ipomoea pes-caprae, Spartina ciliata, Hydrocotyle bonariensis and Paspalum vaginatum.* The species *Ipomoea pes-caprae* was evenly distributed along this geomorphological unit. In a lower proportion, and with low CVI values, *Blutaparon portulacoides*, *Canavalia rosea*, *Vigna* sp. and *Polygala cyparissias*individuals were observed.

Multivariate statistical analysis

The cluster analysis of the six geomorphological units considering 28 variables (Figure 3) led to the formation of two sample groups, with greater similarity in group 1, between geomorphological units 2, 3, 5 and 6. Group 2, comprising units 1 and 4, presented lower relation, observed by the greater distance of similarity and the adopted cutoff point (70). The Principal Components Analysis (PCA) indicated the same sectorization tendency pointed out in the Cluster analysis, with the formation of two isolated groups: a) group 1 consisting of units 2, 3, 4 and 5; B) group 2 consisting of units 1 and 4. Group 1isolation was conditioned mainly by the positive correlation with the geomorphometric variables and the isolation of group 2 was conditioned mainly by the vegetative variables. Group 1 consists of geomorphological units with an average area of 37,205.25m^2, with average altitude of 2.83m, sediment volume of 64,651.75m^3 above the sea level and high ratio volume/area of 1.54m^3/m^2. The sandspits have average width of 21,75m and average age of 28,25 years, and hydrodynamics classified as sheltered, dominated by tides and under wind influence. The vegetative aspects show an occurrence of 204 individuals, with an average absolute frequency of 28.14%, average relative frequency of 13.79%, average absolute coverage of 143.41%, and average relative coverage of 13.79%. Group 2 consists of geomorphological units with average area of 29,830.50m^2, average elevation of 2.49m, sediment volume of 29,830.50m^3 above the sea level and low ratio volume/area, of 0.63m^3/m^2. The sandspits have average width of 13.18m and average age of 11.5 years, with hydrodynamics classified as exposed, dominated by wave and influenced by tides. The vegetative aspects show an occurrence of 120 individuals, with average absolute frequency of 21.82%, average relative frequency of 9.09%, average absolute coverage of 73.61%, average relative coverage of 9.09%.

DISCUSSION

The sand spit develops according to the direction of the coastal longshore currents (longitudinal currents) and the result of sedimentary transport, due to the wave occurrence predominant direction (Komar, 1976). Capri beach has a high dynamism regarding the morphology of the depositional environment, with successive and cyclical interruptions in the sedimentary transport, with incidence of low amplitude waves and great obliquity in relation to the coastline (Vieira, 2015; Randazzo, Jackson, Cooper, 1998).Capri beach can be classified in the intermediate morphodynamic stage of low tide terrace (Wright & Short, 1984; Vieira, 2015), but, however, Silveira *et al*. (2011) classified the same beach as being reflective. In group 1 were inserted the geomorphological units classified as sheltered from the effects of waves, influence or dominate the physical processes, such as influence of tides and wind. Geomorphological units 2, 3, 5 and 6 (Group 1) have higher average age, larger average width and higher sediment accumulation per area.

These geomorphological units have greater geological stability, with the performance of essentially depositional processes, without frequent occurrence of erosion events. It was observed that on Capri beach the geomorphological units exposed to the action of waves (Group 2), have smaller volumes of sediment per area, reduced average width and average age of recent formation. These units are exposed to the sediment transport oscillation and the effects of waves, providing erosion and deposition along the coastline. In this sense, the geomorphological units 1 and 4 (Group 2) act as barriers, safeguarding the environments located in the backbarrier (Group 1). According to Hay *et al*. (1981), restinga habitats are fragile environments due to the nature of their particularly poor soil, composed of unconsolidated sand and, in many areas, a considerable degree of salinity. Therefore, the vegetation occurred in these environments is classified as halophyte-psamophyta (Barros *et al*., 1991; Almeida & Araújo, 1997). The plants are considered halophytes given the salt tolerance and sporophytes given the tolerance to high substrate mobility. The characteristics of these plants allow them to survive even with substrate instability (Almeida & Araújo, 1997). The species sampled in the geomorphological units have adaptations that allow them to grow, develop and reproduce in sandy environments formed by spurs. For the sandy coast of the state of Santa Catharina psamophyte species as represented by *Canavalia rosea* and *Hydrocotyle bonariensis* are found (Stellfeld, 1949).

Also occurring, with great importance in the organization of the vegetative communities, the species described below. Species comprising Group 1 are recognized as important dune fixers, controlling the erosion process in the coastline (Cordazzo *et al*., 2006). This can be explained by the stem morphology, which is generally formed by long stolons or fast growing rhizomes that allow to reach an extensive area of ground cover (IBGE, 2012). In addition to the ecological function of stabilization of the sandy sediment, the occurrence of *Canavalia rosea* and *Ipomoea pes-caprae* finds its southern limit of geographical distribution in the Santa Catarina coast (Cordazzo & Seeliger 1988). Similarly to the species particular to the previous group, the formers of Group 2 also perform the role of bonding the sandy sediment. The species *Spartina ciliata* seems to be more resistant to the action of the winds and tolerate larger fluctuations in salinity content (Cordazzo *et al*., 2006).

Conclusion

Capri beach is characterized by oblique waves with the formation of successive sandspits, high dynamism in terms of depositional environment morphology, with successive and cyclical interruptions in the sedimentary transport. In the floristic survey 323 vegetation specimens of 18 species were recorded, and distributed in 18 gender and 11 families. The families with the highest number of species were: *Fabaceae* (4), *Poaceae* (3), *Amaranthaceae and Asteraceae* (2). Along the area under study, the herbaceous species *Ipomoea pes-caprae* and *Spartina ciliata were*outstanding for their efficiency in supporting physical-chemical variations. For the phytosociological parameters, the highest CVI index was observed for the *Ipomoea pes-caprae* species, which represents greater importance in the community organization.
The statistical analysis of interaction between the geomorphological and vegetative variables presented the formation of two groups. Group 1 is sheltered from the action of waves and suffers greater influence of wind and tide processes, has higher average age, greater average width and larger sediment accumulation. These areas have greater geological stability, with essentially depositional processes, without the frequent occurrence of erosion events. It is noteworthy that the species identified in group 1 are recognized as important dune fixers, depending on the stem morphology. Group 2 is exposed to the action of waves, has lower sediment volume, reduced average width and lower average age. This region is exposed to the action of waves and subject to retractions to the aggradation of the coastline, being predominantly colonized by *Spartina ciliata.*

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