Journal of Coastal Research	9	2	317-323	Fort Lauderdale, Florida	Spring 1993

Zoned Habitats of Southern Brazilian Coastal Foredunes

Cesar V. Cordazzo and U. Seeliger

Laboratorio de Botanica Marinha
Departamento Oceanografia
Universidade do Rio Grande
C.P. 474
96200 Rio Grande RS, Brazil

ABSTRACT

CORDAZZO, C.V. and SEELIGER, U., 1993. Zoned habitats of southern Brazilian coastal foredunes. *Journal of Coastal Research*, 9(2), 317-323. Fort Lauderdale (Florida), ISSN 0749-0208.

Different foredune physiographies characterize the Atlantic coast of Brazil's extreme south. Classification and ordination techniques were used to define plant associations and habitat types based on vegetation biomass, sand stability, and depth of water table, in a coastal region characterized by a "high foredune" physiography. Typical habitats are formed by a frontal dune ridge and a landward positioned sheltered area. Local environmental variants cause retraction of driftline habitats and cyclic formation of an embryo dune habitat.

ADDITIONAL INDEX WORDS: *Coastal foredunes, habitats, plant associations, ordination, classification.*

INTRODUCTION

The interactions between environmental processes and biological responses of foredune plants produce different types of coastal foredune physiographies (GODFREY, 1977) and habitats (BARBOUR, 1987). High foredune ridges, hummock dunes and sand plains are common foredune physiographies and all occur along the southern Brazilian coast (SEELIGER, 1992). A comparative scheme of zoned habitats for different coastal foredune physiographies was proposed by DOING (1985). The division of the foredune complex into five habitats, based on soil, water, and floristic elements, proved to be valid for many of the world's coastal dunes. Ephemeral and perennial tidemarks, embryo dunes, a foredune ridge, and a sheltered area are typical foredune habitats. Zonation patterns are particularly well defined on shores exposed to onshore winds and tides in warm-temperate and humid climates. These conditions apply to the southwestern Atlantic shoreline of southern Rio Grande do Sul State, Brazil, where coastal foredunes are colonized exclusively by herbaceous plants (CORDAZZO and SEELIGER, 1988).

This study describes zoned habitats in dunes with a high foredune physiography. The principal plant associations and the environmental factors which control their zonation are identified.

92030 received 27 March 1992; accepted in revision 26 August 1992.

MATERIAL AND METHODS

A study area (32°40′S; 52°30′W) of 20 × 340 m, fringed by the leading edge of the beach vegetation and an inland freshwater marsh, was divided into seventeen contiguous 20 × 20 m sampling plots. The local predominance of rhizomatous species with unknown ramet size made individual counts of shoots and density determination questionable. Under these circumstances biomass estimates of the vegetation reflect more closely the distribution of plants (ONYEKWELU, 1972; PEMADASA *et al.*, 1974) in relation to abiotic resources available for each species (WILHN, 1968). The above-ground plant biomass was removed from 10 randomly placed 0.5 × 0.5 m squares in each sampling plot, then separated by species, dried at 75 °C for 24 hr and weighed. Sand accretion-erosion and the water table depth were measured monthly for one year in all sampling plots with wooden stakes and PVC tubes, respectively (CORDAZZO, 1985; COSTA *et al.*, 1991).

The data were analyzed, using both classification and ordination techniques to improve their interpretation (GAUCH, 1982). Sampling plots were hierarchically classified by Group Analysis (ROMESBURG, 1984), using dry weight biomass of species (frequency >5%) as an attribute for classification (KACHI and HIROSE, 1979; HENRIQUES *et al.*, 1981). The Pearson correlation coefficient was used as similarity index and the final dendrogram was based on the floristic similarity be-

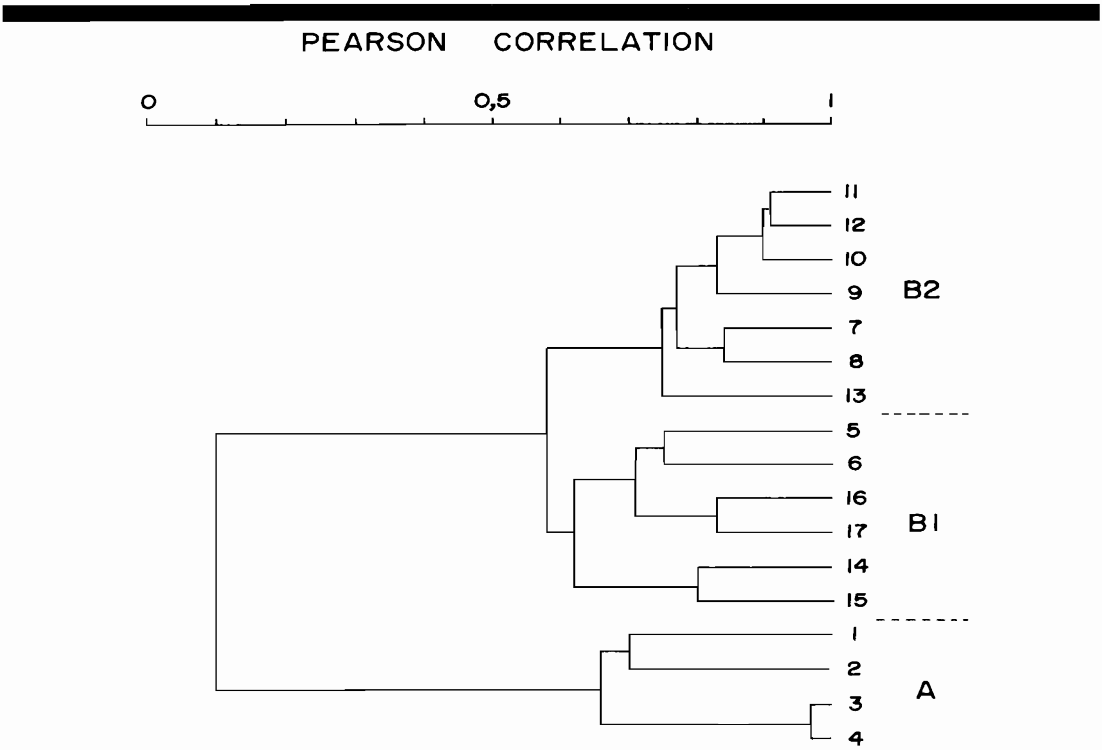

Figure 1. Hierachical classification with Pearson correlation coefficient of sampling plots in southern Brazilian foredunes based on dry weight biomass of species and grouped into associations A, B1, and B2.

tween samples according to the Weighted Pair Group Method using arithmetic averages (WPGMA) after all variables were standardized (Pielou, 1984).

As ordination technique, Detrended Correspondence Analysis (DCA) was chosen (Hill, 1979), based on the biomass of species and abiotic data from each plot. This technique has been successfully applied to dune systems elsewhere (Van Der Maarel *et al.*, 1985; Moreno-Casasola and Espejel, 1986). Means of abiotic factors between groups were tested ($P < 0.05$) using One-Way-ANOVA followed by Scheffe "*a posteriori*" test of multiple comparisons.

RESULTS

Of the 33 species collected in the local dunes with high foredune physiography the biomass values of 19 (relative frequencies >5%) were used for analysis. Highest frequencies were observed for *Hydrocotyle bonariensis* (60.6%), *Androtrichum trigynum* (55%), *Andropogon arenarius* (42%), *Panicum racemosum* (35.5%) and *Imperata brasiliensis* (30%). Both cluster analysis and DCA were consistent in that they defined identical groups, eliminating the chance of artificial grouping as a result of the techniques applied.

Cluster analysis defined two associations (A and B) with less than 10% similarity. Association B divided into two vegetation types (B1 and B2) with less than 60% similarity (Figure 1). The means of abiotic factors were significantly different between these groups (Table 1). Association A was located on foredune ridges with pronounced substrate instability and was composed of *Blutaparon portulacoides, P. racemosum* and *Senecio crassiflorus* (Figure 2, Table 1). Species of association B grew behind the foredune ridges in a sheltered area where sand movement was low (Table 1). At dry locations, with more than 0.5 m water table depth (association B1), *Andropogon arenarius, H. bonariensis, Senecio crassiflorus, Gamochaeta americana* and *Conyza floribunda* were dominant (Figure 2). Accompanying species with low biomass were *Eragrostis trichocolea,*

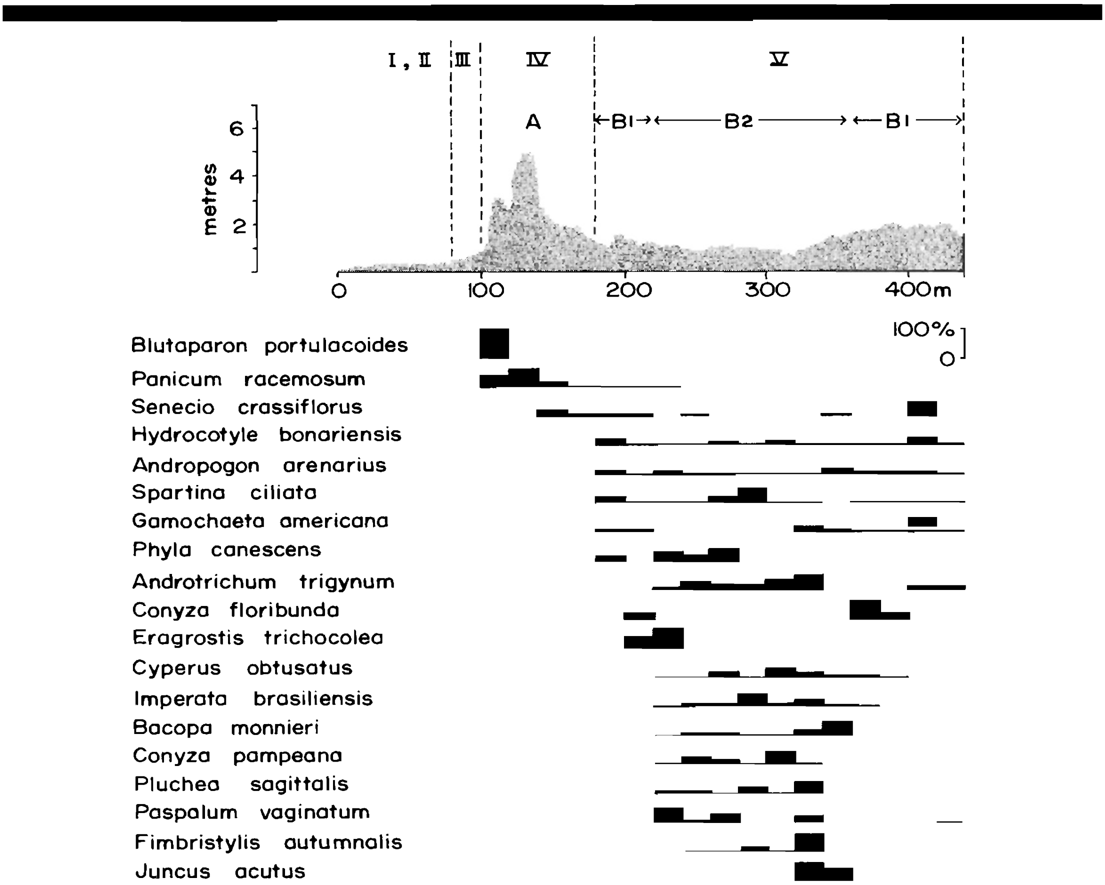

Figure 2. Distribution of plant associations (A, B1, B2) and species biomass (100% represents highest relative biomass of each species) along a beach-inland gradient in a high foredune complex of southern Brazil. Habitat types of the Doing scheme (Doing, 1985) are ephemeral and perennial driftlines (I, II); embryo dunes (III); main foredunes (IV); and sheltered area (V).

Phyla canescens, Androtrichum trigynum, Spartina ciliata, and plants of *P. racemosum* with depauperate growth. Association B2 developed in wet places (water table <0.5 m) (Table 1) with high biomass of *Androtrichum trigynum, Cyperus obtusatus, Spartina ciliata* and *I. brasiliensis* (Figure 2). Several species (*Juncus acutus, Pluchea sagittalis, Conyza pampeana, Fimbrystilis autumnalis*) were exclusive to these humid conditions.

The DCA ordinated species in a similar way (Figure 3). The first two ordination axes explained 76% of the observed variance. Axis 1 represented a gradient of substrate instability between foredune ridges and wet slacks. Axis 2 reflected a humidity gradient between dry and wet slacks in the sheltered area (Table 1). The third axis, due to a low eigenvalue, was not considered.

DISCUSSION

Coastal foredunes do not reflect autogenic succession and habitat types tend to be a result of differences between their initial environmental conditions and changes of abiotic factors there-

Table 1. *Annual means and standard errors of abiotic factors from sampling plots occupied by different plant associations in a southern Brazilian foredune complex. Different letters in a row indicate significant differences (P < 0.05).*

Abiotic Factors	Association A	Association B1	Association B2
Sand movement (cm/month)	8.61 ± 3.79 (a)	1.18 ± 0.44 (b)	0.23 ± 0.07 (c)
Water table depth (cm)	221.72 ± 29.24 (a)	50.00 ± 6.84 (b)	13.53 ± 5.23 (c)

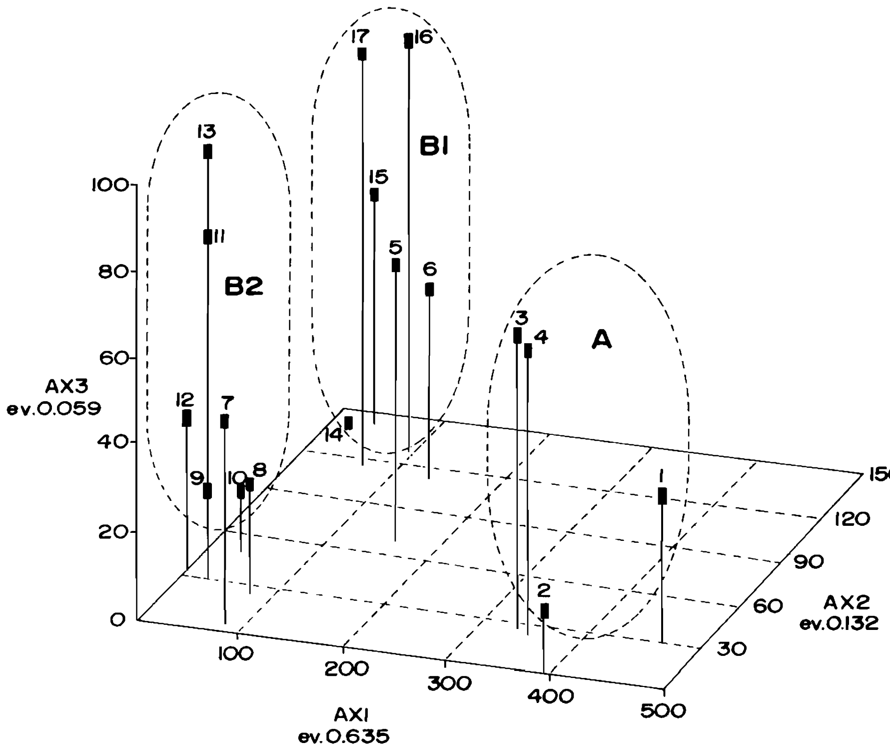

Figure 3. Ordination (DCA) of sampling plots, using species biomass and abiotic data in a southern Brazilian foredune complex with associations A, B1, and B2 (ev = eigenvalue). Axes 1 and 2 represent gradients of substrate instability and humidity, respectively.

after. In consequence, the associated vegetation reflects characteristics of pioneer communities (DOING, 1981, 1985). Site-specific factors influence the ecology of plants in each habitat (BARBOUR *et al.*, 1976), though there is no consensus which abiotic factor is most important. The composition of plant communities and the biology of their populations have been attributed to spatial and temporal gradients of sand instability (HARRIS and DAVY, 1986), hydrologic conditions (PAVLIK, 1985), and nutrient levels (KLINKHAMER and DE JONG, 1985). Cluster and correspondence analysis of our data indicate that plant associations in the southern Brazilian foredune complex are principally regulated by sand movement and water table depth.

Sand instability selects for monospecific communities of grasses (DOING, 1981; MORENO-CASASOLA and ESPEJEL, 1986), like *Panicum racemosum* of association A. Sand erosion and accretion not only induce stressful growth conditions (WIEDEMANN, 1984), but also control the success of seed germination and seedling establishment (MAUN, 1984; HARRIS and DAVY, 1986), and reduce or prevent invasion of frontal dunes by other species (MORENO-CASASOLA, 1986). At sites with some sand stability other species might contribute to increased diversity (DOING, 1981). *Blutaparon portulacoides* and *Senecio crassiflorus* of association A encounter these conditions at the foot of the frontal dune ridge with increased sand humidity and on more protected foredune ridges with less wind exposure, respectively (PFADENHAUER, 1980).

Immediately behind the foredune ridges sand movement is arrested and the substrate becomes stabilized thus permitting an increasing number of species to become established and to grow (CARTER, 1988). Therefore association B, in contrast to association A, has higher species diversity and vegetation cover (CORDAZZO and SEELIGER, 1987). Local variations in water table depth (dry and wet slacks) in this area result from long term differences in sand burial rates and wind-induced deflation processes (PFADENHAUER and RAMOS, 1979).

In dry slacks the rhizomatous, perennial and highly opportunistic *Hydrocotyle bonariensis* (ORMOND, 1960; PFADENHAUER, 1980) dominates association B1 together with the grass *Andropogon arenarius. Hydrocotyle bonariensis* shows rapid vegetative growth, a high degree of phenotypic plasticity, and density-dependent population control (COSTA and SEELIGER, 1988). Seedling establishment and/or sprouting buds of *A. arenarius* are favoured in dry slacks, because in wet slacks this species competes for nutrients and space with tall clumps of *S. ciliata* and *Androtrichum trigynum* (COSTA *et al.*, 1988a). Senescent and depauperate growth of *P. racemosum* persist in this habitat. The declining vigour of this species is caused by changes in physico-chemical conditions, biological infestation by nematodes, and competition with other species (COSTA *et al.*, 1991).

Seasonally flooded wet slack habitats are characterized by low nutrient levels and acid soils (CORDAZZO, 1985) and they are usually occupied by grasses and sedges (CORDAZZO, 1985; MORENO-CASASOLA and ESPEJEL, 1986) with pronounced influence on dune structure and physiognomy (PFADENHAUER, 1980). The wet slack association B2 is dominanted by *Androtrichum trigynum* (Cyperaceae), endemic to the southwestern Atlantic coast. The species tolerates flooded conditions because of extensive aerenchymatic tissue in roots and rhizomes (COSTA *et al.*, 1988b). Co-occuring grasses, like *Imperata brasiliensis, Paspalum vaginatum,* and *S. ciliata* are local indicators of wet conditions (PFADENHAUER, 1978, 1980; CORDAZZO and SEELIGER, 1987).

The unifying concept applied to the classification of foredune complexes (DOING, 1985) emphasizes the dynamics of allogenic and vegetative processes common to a sand dune landscape, without neglecting local or regional variants. In southern Brazilian coastal dunes with high foredune physiography, Doing's main foredune and sheltered area habitats are typically represented by sites with associations A and B, respectively. However, in this region the definition of Doing's sheltered area habitat type may be too broad because differences in vegetation composition, biomass and environmental conditions clearly subdivide this habitat into wet and dry sub-habitats.

As a result of local variants such as wind-controlled beach inundation and frequent storm tides with strong erosive action on the shore, Doing's annual and perennial beach and driftline habitats are absent along this coast. The annuals *Cakile maritima* and *Calycera crassifolia,* common to driftlines elsewhere (ESKUCHE, 1973; DOING, 1985; MORENO-CASASOLA and ESPEJEL, 1986), occur sporadically along the coast and where present, retract to more protected sites at the base of the frontal dune ridge (CORDAZZO, 1985; SEELIGER, 1992). An ephemeral embryo dune habitat is formed by the forb *Blutaparon portulacoides.* Cyclic events of extreme storm tides erase the plant population and embryo dunes in intervals of several years (BERNARDI *et al.*, 1987). Re-colonization of the backshore and re-establishment of embryo dunes is favoured by the halophytic nature of *B. portulacoides* and its high capacity to regenerate from rhizome fragments (PFADENHAUER, 1978; BERNARDI and SEELIGER, 1989). Prior to destruction by storm tides, well established embryo dunes near the base of the foredune ridge are slowly invaded by *Panicum racemosum.*

In conclusion, zoned habitats of the southern Brazilian coastal foredunes largely correspond with the zonation scheme proposed by DOING (1985), though regional and local variants must be taken into consideration. Future studies will evaluate the validity of zoned habitats in southern Brazilian coastal hummock dune and sand plain physiographies.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. C.S.B. Costa for his critical comments of the manuscript and the Conselho Nacional de Desenvolvimento Cientifico e Tecnologico (CNPq), Brazil, for financial support during the study.

LITERATURE CITED

BARBOUR, M.G., 1987. Beach vegetation and plant distribution patterns along the northern Gulf of Mexico. *Phytocoenologia,* 15(2), 201–233.

BARBOUR, M.G.; JONG, T.M., and JOHNSON, A.F., 1976. Synecology of beach vegetation along the Pacific coast of United States of America: A first approximation. *Journal of Biogeography,* 3, 55–69.

BERNARDI, H.; CORDAZZO, C.V., and COSTA, C.S.B., 1987. Efeito de ressacas sobre *Blutaparon portulacoides* (St.Hil.) Mears, nas dunas costeiras do Sul do Brasil. *Ciencia e Cultura,* 39(5/6), 545–547.

BERNARDI, U. and SEELIGER, U., 1989. Population biology of *Blutaparon portulacoides* (St.Hil.) Mears on southern Brazilian backshores. *Ciencia e Cultura,* 41(11), 1110–1113.

CARTER, R.W.G., 1988. *Coastal Environments*. London: Academic, 392p.

CORDAZZO, C.V., 1985. Taxonomia e Ecologia de Vegetacao das Dunas Costeiras ao Sul do Cassino (RS). M.Sc. Thesis, Universidade do Rio Grande, Brazil.

CORDAZZO, C.V. and SEELIGER, U., 1987. Composicao e distribuicao da vegetacao nas dunas costeiras ao sul de Rio Grande (RS). *Ciencia e Cultura*, 39(3), 321–324.

CORDAZZO, C.V. and SEELIGER, U., 1988. Phenological and bio-geographical aspects of coastal dune plant communities in southern Brazil. *Vegetatio*, 75, 169–173.

COSTA, C.S.B.; SEELIGER, U., and CORDAZZO, C.V., 1988a. Distribution and phenology of *Andropogon arenarius* Hackel on coastal dunes of Rio Grande do Sul, Brazil. *Revista Brasileira de Biologia*, 48(3), 527–536.

COSTA, C.S.B.; SEELIGER, U., and CORDAZZO, C.V., 1988b. Dinamica populacional e distribuicao horizontal de *Androtrichum trigynum* (Spreng.) Pfeiffer (Cyperaceae) em brejos e dunas costeiras do Rio Grande do Sul, Brasil. *Acta Limnologica Brasileira*, 11, 813–842.

COSTA, C.S.B. and SEELIGER, U., 1988. Demografia de folhas do *Hydrocotyle bonariensis* Lam., uma planta herbacia rizomatosa perene, nas dunas costeiras do Rio Grande do Sul. *Revista Brasileira de Biologia*, 48(3), 443–451.

COSTA, C.S.B.; SEELIGER, U., and CORDAZZO, C.V., 1991. Leaf demography and decline of *Panicum racemosum* in coastal foredunes of southern Brazil. *Canadian Journal of Botany*, 69, 1593–1599.

DOING, H., 1981. A comparative scheme of dry coastal sand dune habitats, with examples from the eastern United States and some other temperate regions. *Veröffentlichungen Geobotanisches Institut* ETH, Stiftung Rübel, 77, 41–72.

DOING, H., 1985. Coastal fore-dune zonation and succession in various parts of the world. *Vegetatio*, 61, 65–75.

ESKUCHE, U., 1973. Pflanzengesellschaften der Küstendünen von Argentinien, Uruguay und Südbrasilien. *Vegetatio*, 28, 201–250.

GAUCH, H.G., JR., 1982. *Multivariate Analysis in Community Ecology*. New York: Cambridge University Press, 298p.

GODFREY, P.J., 1977. Climate, plant response and development of dunes on barrier beaches along the U.S. east coast. *International Journal of Biometeorology*, 21(3), 203–215.

HARRIS, D. and DAVY, A.J., 1986. Regenerative potential of *Elymus farctus* from rhizome fragments and seed. *The Journal of Ecology*, 74, 1057–1067.

HENRIQUES, R.P.B.; MEIRELES, M.L., and HAY, J.D., 1981. Ordenacao e distribuicao de especies de comunidades vegetais na praia da restinga de Marica, Rio de Janeiro. *Revista Brasileira de Botanica*, 7, 27–36.

HILL, M.O., 1979. *Decorana—A FORTRAN Program for Detrended Correspondence Analysis and Reciprocal Averaging*. Cornell University, Ithaca, New York, 36p.

KACHI, N. and HIROSE, T., 1979. Multivariate approaches to the plant communities related with edaphic factors in the dune system at Azigaura, Ibaraki Pref. I. Association-analysis. *Japanese Journal of Ecology*, 29, 17–27.

KLINKHAMER, P.G.L. and DE JONG, T.J., 1985. Shoot biomass and species richness in relation to some environmental factors in a coastal dune area in the Netherlands. *Vegetatio*, 63, 129–132.

MAUN, M.A., 1984. Colonizing ability of *Ammophila breviligulata* through vegetative regeneration. *The Journal of Ecology*, 72, 565–574.

MORENO-CASASOLA, P., 1986. Sand movement as a factor in the distribution of plant communities in a coastal dune system. *Vegetatio*, 65, 67–76.

MORENO-CASASOLA, P. and ESPEJEL, H., 1986. Classification and ordination of coastal sand dune vegetation along the Gulf and Caribbean Sea of Mexico. *Vegetatio*, 66, 147–182.

ONYEKWELU, S.S.C., 1972. The vegetation of dune slacks at Newborough Warren. I. Ordination of the vegetation. *The Journal of Ecology*, 3, 887–898.

ORMOND, W.T., 1960. Ecologia das restingas do sudeste do Brasil. Comunidades Vegetais das praias arenosas. *Arquivos do Museo Nacional do Rio de Janeiro*, 50, 185–236.

PAVLIK, B.M., 1985. Water relations of the dune grasses *Ammophila arenaria* and *Elymus mollis* on the coast of Oregon, USA. *Oikos*, 45, 197–205.

PEMADASA, M.A.; GREIG-SMITH, P., and LOVELL, P.H., 1974. A quantitative description of the distribution of annuals in the dune system at Aberggraw, Anglesey. *The Journal of Ecology*, 62, 379–402.

PFADENHAUER, J., 1978. Contribuicao ao conhecimento da vegetacao e de suas condicoes e crescimento nas dunas costeiras do Rio Grande do Sul, Brasil. *Revista Brasileira de Biologia*, 38, 827–836.

PFADENHAUER, J., 1980. Die Vegetation der Küstendünen von Rio Grande do Sul, Südbrasiliens. *Phytocoenologia*, 8, 321–364.

PFADENHAUER, J. AND RAMOS, R.F., 1979. Um complexo de vegetacao entre dunas e pantanos proximos a Tramandai, Rio Grande do Sul, Brasil. *Iheringia Botanica*, 25, 17–26.

PIELOU, E.C., 1984. *The Interpretation of Ecological Data*. New York: Wiley, 263p.

ROMESBURG, H.C., 1984. *Cluster Analysis for Researchers*. Belmont: Lifetime Learning Publications, 334p.

SEELIGER, U., 1992. Coastal foredunes of southern Brazil: Physiography, habitats, and vegetation. *In:* U. SEELIGER (ed.), *Coastal Plant Communities of Latin America*. San Diego: Academic, pp. 367–381.

VAN DER MAAREL, E.; BOOT, R.; VAN DORP, D., and RIJNTJES, J., 1985. Vegetation succession on the dunes near Oostvoorne, the Netherlands: A comparison of the vegetation in 1959 and 1980. *Vegetatio*, 58, 137–187.

WIEDEMANN, A.M., 1984. The ecology of Pacific Northwest coastal sand dunes: A community profile. *U.S. Fish Wildlife Service FWS/OBS*-84/04. 130p.

WILHN, A.J., 1968. Use of biomass units in Shannon's formula. *Ecology*, 49, 153–156.

□ RESUMO □

Diferentes fisiografias de dunas costeiras caracterizam a costa Atlantica no extremo sul do Brasil. Foram usadas tecnicas de classificacao e ordenacao para definir associacoes de vegetacao e habitats na regiao costeira referente a fisiografia de dunas frontais, tomando como base dados de biomassa vegetal, estabilidade da areia e distancia ao lencol freatico. Os principais habitats sao formados pelas cristas de dunas frontais e mais internamente por uma area protegida. Variacoes ambientais locais causam uma retracao nos habitats de "driftline" e ciclos na formacao do habitat de dunas embrionarias.