Rodriguésia 63(3): 513-524. 2012
http://rodriguesia.jbrj.gov.br

Phytosociology and natural subtropical grassland communities on a granitic hill in southern Brazil

Fitossociologia e comunidades de campos subtropicais naturais em um morro granítico no sul do Brasil

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Abstract
A phytosociological survey was carried out in a study area located at Serra do Sudeste, southern Brazil, where forests and grasslands are distributed in a mosaic, seeking to unravel diversity patterns in four different grassland communities. Grassland management traditionally adopted by the local population is characterized by burning practices that aim to eliminate woody species, delaying the forest expansion process that is favored by the extant climate. The number of plots distributed per community was as follows: rocky grasslands (17), dry grasslands (33), moist grasslands (15) and marshy grasslands (5). Different numbers of plots were used due to the natural conditions of these communities, with highest cover for dry grasslands, followed by rocky, moist and marshy grasslands. Data analyses consisted of calculating community indexes and parameters and exploratory multivariate analysis. We verified that c. 15% of species among the 177 registered taxa were highly dominant in the constitution of the vegetation matrix in all communities, whereas most of the species showed low frequency and cover values. Rocky and dry grasslands showed higher similarity and diversity indexes than moist and marshy grasslands. We concluded that the large number of rare or intermediate-frequency species is decisive for the high diversity found in these grasslands.
Key words: Pampa biome, diversity, rare species, fire.

Resumo
Um levantamento fitossociológico foi realizado em uma área de vegetação campestre localizada na Serra do Sudeste, sul do Brasil, onde campos e florestas estão distribuídos em mosaico, buscando compreender padrões de diversidade em quatro comunidades. O manejo destes campos realizado pela população local é caracterizado por práticas de queimadas periódicas visando eliminar espécies lenhosas, retardando assim o processo de expansão florestal favorecido pelo clima atual. O número de parcelas por comunidade foi: campo rupestre (17), campo seco (33), campo úmido (15), campo brejoso (5). Diferentes totais de parcelas foram utilizados devido às condições naturais dessas comunidades, com uma alta cobertura de áreas de campo seco, seguido pelos campos rupestres, úmidos e brejosos. A análise de dados consistiu no cálculo de índices e parâmetros fitossociológicos e análises multivariadas exploratórias. Verificou-se que aproximadamente 15% dos 177 táxons registrados apresentaram maior dominância na composição da vegetação nas quatro comunidades, enquanto a maioria das espécies apresentou baixos valores de frequência e cobertura. Maiores índices de similaridade e diversidade foram encontrados entre campos secos e rupestres do que entre campos úmidos e brejosos. Conclui-se que o grande número de espécies raras e de frequência intermediária é determinante para os elevados índices de diversidade encontrados nestes campos.
Palavras-chave: bioma Pampa, diversidade, espécies raras, fogo.

This paper has additional data published in its electronic version.

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Introduction

In southern South America, there is a grassland formation inserted in the Pampa Biome, regionally recognized as "campos grasslands", that extends as far as Uruguay, eastern Argentina and southern Brazil (Rosengurtt 1944; Burkart 1975; Bilenca & Minarro 2004). In Brazil, this biome is found exclusively in the southern half of the state of Rio Grande do Sul (RS), and shows high species richness and foraging value (Overbeck *et al.* 2007). The plant diversity found in these grasslands is the result of a long evolutionary history and extensive habitat variation that occurs along the environmental gradient present between the coast and the continent interior (Boldrini 2007). Events of climatic fluctuation that took place during the quaternary shaped a complex vegetation mosaic, due to the interpenetration of forests in grassland areas, which makes these formations difficult to delimitate and controversial concerning about an adequate classification system (Lindman 1906; Rambo 1956; Teixeira *et al.* 1986; Pillar & Quadros 1997; Boldrini 1997; Marchiori 2002; Boldrini 2009).

According to Boldrini (2009), grassland vegetation at the Pampa biome, present in RS, shows eight different phytophysiognomies related to the variation of dominant species and ambient factors in different geomorphological provinces of the state. The chain of granitic hills present in Porto Alegre city (RS), which belongs to the geological formation locally known as Serra do Sudeste, presents the "Savanoid Vegetation"phytophysiognomy. In this region, grasslands and forests occur in mosaics, the first usually occupying smaller areas, restricted to hilltops and isolated by forests present in hillsides and surrounding plains. The savanoid physiognomy is characterized by the occurrence of eventual patches or isolated individuals of ligneous shrubs and pioneer tree species in grasslands. The progressive increase of ligneous species over grasslands offers conditions to the establishment and development of other tree species in the surroundings, leading to a slow process of forest advance through nucleation and border expansion dynamics (Muller & Forneck 2004; Oliveira & Pillar 2004; Behling *et al.* 2007; Pillar *et al.* 2009). The ongoing process of forest expansion is linked to the hot and moist climate of the last 4,000 years, and was intensified in the last thousand years (Behling 2002; Behling *et al.* 2007). The human management of the grasslands consists on periodical burnings, traditionally used to eliminate the biomass of ligneous species and cespitose grasses that progressively dominate these formations. Since grazing activities are low in Porto Alegre region, fire is predominantly used to maintain the grassland matrix, and the renewing of pastures for animal foraging is of lesser interest. Fire also slows down the process of forest expansion, and shapes a complicated mosaic of vegetation in different successional stages (Pillar & Quadros 1997; Behling *et al.* 2007; Muller *et al.* 2007).

Besides the regional suggestions of classification for the grasslands of RS state and the lack of consensus among them, there are few quantitative studies with suggestions of community classification in the local scale (e.g., Focht & Pillar 2003; Ferreira & Setubal 2009). Setubal & Boldrini (2010) qualitatively investigated a natural grassland remnant in a granitic hill at Porto Alegre, Serra do Sudeste, identifying floristic groups and their association with environmental variables, suggesting a classification of four plant communities. The present study aims for the complement of this knowledge by comparatively evaluating these communities through quantitative patterns such as abundance, richness, diversity and similarity. We believe that a larger number of local studies might be the basis for a better comprehension of floristic and ecological patterns in the different phytophysiognomies that constitute the grasslands of the Pampa biome in RS state.

Material and Methods

Study area

The study area is located at Morro São Pedro (30º10'S; 51°06'W; 289 m maximum altitude), Porto Alegre municipality, RS, an elevation that is part of the chain of granitic hills that belongs to the Serra do Sudeste (or Crystalline Shield) (Rambo 1956; Suertegaray & Fujimoto 2004). Climate at the region is moist-subtropical (Cfa according to the Köppen's classification) with annual mean temperature ranging between 18 and 20ºC and annual mean rainfall between 1300 and 1500 mm, without drought season (Nimer 1990).

Geology is constituted by Viamão granite that originated Argisols (hillsides), Cambisols and Neosols (hilltops and upper hillsides), characterized by low fertility and moderate to strong acidity (Streck *et al.* 2008; Schneider *et al.* 2008). Vegetation comprises ca. 692 ha of forests and 440 ha of grasslands, which occur in mosaic (Güntzel *et al*. 1994). Grasslands predominantly occupy hilltops and hillsides, whereas forests predominate in southern hillsides, and this is the general vegetation distribution pattern at the local granitic hills (Aguiar *et al.* 1986).

Phytosociological survey

For the quantitative sampling, we carried out a phytosociological survey between October and December 2008, in grassland patches distributed in the central and southern portions of Morro São Pedro, summing up ca. 80 ha of sampling area. Sampling was carried out in four communities that were recognized according to the classification based on Setubal & Boldrini (2010): Rg = rocky grassland; Dg = dry grassland; Mog = moist grassland; Mag = marshy grassland (Tab. 1). Four different environmental sites of each community were selected for sampling. These sites were of different area sizes due to the natural conditions of these communities, with high cover of dry grasslands, followed by rocky, moist and marshy grasslands. In the marshy grassland community we used only one sampling site, due to the lack of another similar environment, summing up a total of 13 sites sampled. Transects were established along the core areas of each site, and sampling units were systematically placed in regular intervals of 15 m. In sites where they were used more than one transect, the distance between transects was 15 m too. We performed a total of 70 sampling units of 1 × 1 m (size was defined based on local vegetation size), and the number of sampling units per community was: Dg = 33; Rg = 17; Mog = 15; Mag = 5. In each sampling unit we quantitatively evaluated composition and the abundance of each registered species (only angiosperms) through identification and cover estimating using a modification of the decimal scale of Londo (1976) (Tab. 2). Vouchers of all the species registered in the survey were deposited in the Herbarium ICN.

Data analyses

For each species we calculated the following phytosociological parameters: absolute and relative frequency (FA and FR), absolute and relative cover (CA and CR) and index of importance value (IVI) (Boldrini & Miotto 1987). We also calculated the Shannon-Wiener diversity index and the equitability based on the values of relative cover of each species (Krebs 1999). Sample sufficiency was estimated by the rarefaction curve with bootstrap resampling with 1000 iterations and confidence interval of 95% using the software PAST (Hammer *et al.* 2001) and by the non-parametric estimator

Table 1 — Description of general relief, draining and soil factors (type and thickness) in four grassland communities sampled in a phytosociological survey at Morro São Pedro, Porto Alegre municipality, RS state, Brazil. Adapted from Setubal & Boldrini (2010) and Schneider *et al*. (2008). Rg = rocky grassland; Dg = dry grassland; Mog = moist grassland; Mag = marshy grassland.

Communities	Predominant position in the relief	Relief	Draining	Soil types	Soil thickness
Rg	tops and upper slopes	montane to moderately undulated	well drained to moderately drained	haplic cambisols, litholic neosols, regolitic neosols	shallow soils with less than 1 m, up to deep, occurring or not rocky layer starting at 50 cm or less from the surface
Dg	terraces, middle and bottom slopes	strongly undulated to smoothly undulated	well drained to moderately drained	haplic cambisols, red argisols, red-yellow argisols	shallow to deep soils, thickness ranging between less than 1 m until 1.5 m or more to the altered rock
Mog	terraces	flat to smoothly concave	moderately drained to imperfectly drained	haplic cambisols, red argisols, red-yellow argisols	shallow to deep soils, thickness ranging between less than 1 m until 1.5 m or more to the altered rock
Mag	terraces	smoothly concave to moderately concave	imperfectly drained to bad drained	haplic cambisols, red argisols, red-yellow argisols	shallow to deep soils, thickness ranging between less than 1 m until 1.5 m or more to the altered rock

Table 2 – Decimal scale values used for sampling cover of the variables in the sampling units.

Scale values	Species cover
0.1	until 1%
0.5	1.1-5%
1	5.1-10%
2	10.1-20%
3	20.1-30%
4	30.1-40%
5	40.1-50%
6	50.1- 60%
7	60.1-70%
8	70.1-80%
9	80.1-90%
10	90.1-100%

of CHAO (Chao 1984). We also performed a multivariate variance analysis (MANOVA) and an ordination (PCoA) with scatter diagrams using software MULTIV (Pillar 2004), evaluating the significance of contrasts among communities based on composition and abundance of sampled species (resemblance measure: chord distance). Analyses of indicator species were carried out with software PC-ORD (McCune & Mefford 1997). The floristic similarity index of Jaccard (Krebs 1999) was calculated between our sampled communities and between our study and three other surveys of grassland vegetation encompassing the chain of granitic hills at Porto Alegre region. The species arrangement in families followed the APG III (2009).

Results

Phytosociological survey

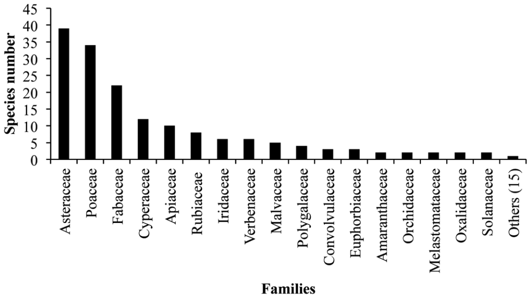
In a sample of 70 sampling units we registered 177 angiosperm taxa, distributed in 32 families and 106 genera (Appendix 1). Among these species, only one (*Maytenus cassineformis* Reissek (Celastraceae)) is a pioneer forest species, so that the remaining species are native to the local grasslands. The five families with higher species richness were Asteraceae (39), Poaceae (34), Fabaceae (22), Cyperaceae (12) and Apiaceae (10), summing up 66.1% of the species sampled in the survey (the first three families correspond to 53% of this total) (Fig. 1).

The rarefaction curve registered a significant increase on its first third part (70% of the species appeared in the first 30% of the sampling units), followed by a progressive decline in the rate of species increase, despite the lack of total stabilization (Fig. 2). The non-parametric diversity estimator of CHAO pointed out 181 expected species for our survey. The actual number of species (97% of the value estimated), coupled with the rarefaction curve and the total sampled area validates the survey's representativeness, showing a significant sampling effort considering the general knowledge of the sampled vegetation.

Six families (Poaceae, Asteraceae, Fabaceae, Apiaceae, Cyperaceae and Iridaceae) condensed the larger sum of phytosociological parameters (FR = 80%; CR = 88,5%; IVI = 84%), but showed two groups with distinct sociological behavior (Tab. 3). Poaceae, Apiaceae and Cyperaceae registered higher cover values in comparison to their respective frequencies, and were responsible for the composition of the vegetation matrix. Out of these three families, six species concentrated ca. 26% of the CR parameter (position considering IVI rating in parentheses): *Sorghastrum albescens* (E. Fourn.) Beetle (1[a]), *Eryngium pristis* Cham. & Schltdl. (2[a]), *Andropogon lateralis* Nees (5[a]), *Scleria balansae* Maury (6[a]), *Schizachyrium tenerum* Nees (7[a]) and *Ischaemum minus* J. Presl (13[a]). Among the 15 grasses present in the first 30 IVI-rated species, 10 showed higher cover values in comparison to frequency. Among them, *I. minus* registered the higher proportional value between cover and frequency.

On the other hand, Asteraceae, Fabaceae and Iridaceae presented higher values of relative

Figure 1 – Botanical families with highest species richness registered in the phytosociological sampling of the grassland vegetation at *Morro São Pedro*, Porto Alegre municipality, RS, Brazil.



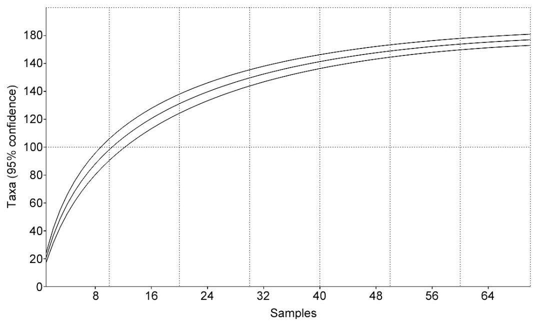


Figure 2 – Rarefaction curve of the phytosociological survey of grassland vegetation at Morro São Pedro, Porto Alegre municipality, RS, Brazil. Total of 177 species in 70 sampling units (1 × 1 m). Bootstrap resampling with 1000 iterations and confidence interval of 95%.

Table 3 – Sum of phytosociological parameters of the 17 botanical families with more than two species in decreasing IVI order (parameters of families with one species can be seen in Appendix I).

Families	FR (%)	CR (%)	IVI (%)
Poaceae	27.76	41.57	34.67
Asteraceae	21.96	18.20	20.08
Fabaceae	13.67	8.94	11.31
Apiaceae	6.56	10.97	8.77
Cyperaceae	4.90	6.07	5.49
Iridaceae	4.83	2.66	3.75
Rubiaceae	4.35	1.98	3.17
Malvaceae	2.21	1.11	1.66
Polygalaceae	1.80	1.10	1.45
Convolvulaceae	1.86	0.71	1.29
Euphorbiaceae	1.66	0.67	1.16
Verbenaceae	1.31	0.80	1.06
Melastomataceae	1.04	0.72	0.88
Amaranthaceae	1.04	0.50	0.77
Oxalidaceae	0.83	0.39	0.61
Solanaceae	0.28	0.20	0.24
Orchidaceae	0.21	0.24	0.22

frequency in comparison to cover, evidencing species that are common in the study area, but of lesser contribution for the vegetation matrix. Examples of these species are (position considering IVI rating in parentheses): *Aspilia montevidensis* (Spreng.) Kuntze (3ª), *Chrysolaena flexuosa* (Sims) H.Rob. (4ª), *Sisyrinchium palmifolium* L. (14ª) and *Macroptilium prostratum* (Benth.) Urb. (24ª). Only five species (three Asteraceae and two Fabaceae) among the first 30 were subshrubs or ligneous shrubs, and all showed higher values of frequency in comparison to cover: *Baccharis cognata* DC. (8ª), *Disynaphia ligulifolia* (Hook. & Arn.) R.M. King & H. Rob. (9ª), *Chromolaena congesta* (Hook. & Arn.) R.M. King & H. Rob. (12ª)*, Collaea stenophylla* (Hook. & Arn.) Benth. (17ª), *Desmanthus virgatus* (L.) Willd. (18ª) and *Centrosema virginianum* (L.) Benth. (22ª). Rubiaceae also stands out due to the frequency values of the eight species registered, all showing usually low cover values.

The pattern of vegetation heterogeneity evidenced that most of the species showed low values of frequency and cover (Figs. 3-4). Among the 177 sampled species, 66% occurred in up to 10% of the sampling units, and 50 species (20%) occurred in only one or two sampling units, and can be considered rare species, whereas the remaining species showed intermediate frequency values. Among the 1448 registries of cover per species, 95% ranged between cover classes 0.1 and 2.0 (64% only in class 0.5) demonstrating the low cover values shown by most species.

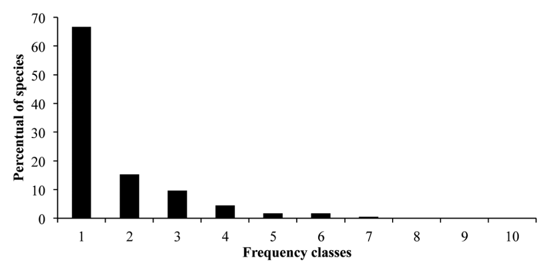


Figure 3 – Percentual distribution of 177 species per class of frequency intervals obtained in the phytosociological sampling of the grassland vegetation at *Morro São Pedro*, Porto Alegre municipality, RS, Brazil. 1 = 1-10%; 2 = 10,1-20%; 3 = 20,1-30%; 4 = 30,1-40%; 5 = 40,1-50%; 6 = 50,1-60%; 7 = 60,1-70%; 8 = 70,1-80%; 9 = 80,1-90%; 10 = 90,1-100%.

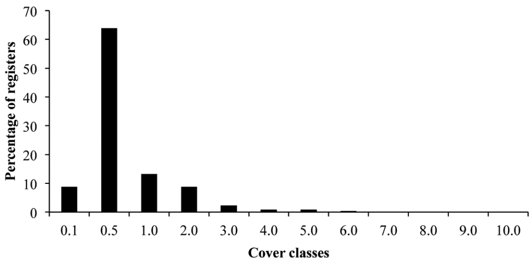


Figure 4 – Percentual distribution of 1448 registers per class of cover obtained in the phytosociological sampling of the grassland vegetation at *Morro São Pedro*, Porto Alegre municipality, RS, Brazil. Scale values used for sampling cover are described in Table 2.

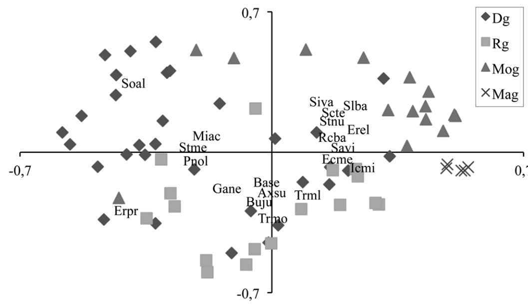


Figure 5 – Ordination diagram of the 70 sampling units (1 m × 1 m) distributed in four plant communities, based on the abundance and composition matrix of 177 species registered in the phytosociological sampling of the grassland vegetation at Morro São Pedro, Porto Alegre municipality, RS state, Brazil. Six species obtained correlation coeficients higher than 0.4 (Soal, Erpr, Trmo, Siva, Icmi, Slba) and 16 obtained values higher than 0.3. Ordination axes explanatory power: 14,4%, 11,2% and 7,4%. Dg = dry grassland (33 sampling units); Rg = rocky grassland (17); Mog = moist grassland (15); Mag = marshy grassland (5); Axsu = *Axonopus suffultus* (Mikan ex Trin.) Parodi; Base = *Baccharis sessiliflora* Vahl.; Buju = *Bulbostylis juncoides* (Vahl) Kük. ex Osten; Ecme = *Eclipta megapotamica* (Spreng.) Sch. Bip. ex S.F. Blake; Erel = *Eryngium elegans* Cham. & Schltdl.; Erpr = *Eryngium pristis* Cham. & Schltdl.; Gane = *Galactia neesii* var. *australis* Malme; Icmi = *Ischaemum minus* J. Presl; Miac = *Mimosa acerba* Benth.; Pnol = *Panicum olyroides* Kunth var. *olyroides*; Rcba = *Rhynchospora barrosiana* Guagl.; Savi = *Saccharum villosum* Steud.; Scte = *Schizachyrium tenerum* Nees; Siva = *Sisyrinchium vaginatum* Spreng.; Slba = *Scleria balansae* Maury; Soal = *Sorghastrum albescens* (E. Fourn.) Beetle; Stme = *Stipa melanosperma* J. Presl.; Stnu = *Stipa nutans* Hack.; Trml = *Trachypogon montufarii* var. *mollis* (Nees) Andersson; Trmo = *Trachypogon montufarii* (Kunth) Nees *var.* montufarii.

Among the species with highest frequency values, only 19 (11%) were registered in 20 or more sampling units, and only six (3.4%) were registered in more than 30 sampling units (*A. montevidensis, C. flexuosa, E. pristis, S. albescens, C. congesta* and *A. lateralis*). Only five families presented cover values per species in class 3.0 or superior: Poaceae (16 species), Cyperaceae, Apiaceae, Asteraceae and Fabaceae (3 species). However, between classes 6.0 to 10.0, besides Poaceae, only Apiaceae (class 6 – *E. pristis*) and Cyperaceae (classes 7 and 8 – *S. balansae*) were represented. Only three species showed cover values between classes 9.0 and 10.0, and all were grasses: *I. minus, S. tenerum* and *S. albescens*.

Analysis of multivariate variance found high significance of contrasts ($p = 0.001$) among the four pairs of communities in comparison to each other. The exploratory ordination analysis grouped together the sampling units in relatively clear sets of communities, arranged in a gradient (Fig. 5), but registered low explanation values for axes 1, 2 and 3 (14.4%, 11.2% and 7.4% respectively). Out of the 20 species that were more correlated with the axes, only six obtained eingenvalues higher than 0.4 (*S. albescens, E. pristis, Trachypogon montufarii* (Kunth) Nees var. *montufarii*, *Sisyrinchium vaginatum* Spreng., *I. minus* and *S. balansae*).

The analysis of indicator species registered 18 significant taxa ($p<0.01$) to recognize the four plant communities we evaluated. Moist grassland communities showed a larger proportion of indicator species/total species in comparison to communities present in drier areas (Mog = 9; Mag = 4; Rg = 4; Dg = 1) (Annex 2 and Tab. 4). Annex 3 shows a comparison between the sets of the 16 species with the highest IVI values registered at the four communities. Species with higher frequency values showed a generalist behavior, occurring in more than one community, such as *A. lateralis* that was present in rocky, moist and marshy grasslands. The vegetation's pattern of heterogeneity in all communities followed the general vegetation pattern, that is, a small group of species condensed the larger portion of the calculated parameters, whereas most species were less expressive in the survey.

Table 4 – Indexes of floristic similarity (Jaccard), total species richness, number and percentage of exclusive species, mean number of species per sampling unit and diversity indexes of Shannon-Wiener (H') and Pielou's equability (E) registered in the 70 sampling units distributed in four grassland communities at Morro São Pedro, Porto Alegre municipality, RS state, Brazil. Rg = rocky grassland; Dg = dry grassland; Mog = moist grassland; Mag = marshy grassland.

	Rg	Dg	Mog	Mag	**species richness**	**exclusives (%)**	**mean**	**H'**	**E**
Rg	1				126	16 (12.7%)	23.6	4.22	0.87
Dg	0.64	1			137	14 (10.2%)	22.1	4.06	0.82
Mog	0.40	0.49	1		89	7 (7.8%)	18.6	3.70	0.82
Mag	0.04	0.04	0.07	1	16	9 (56%)	7.6	1.91	0.69

The diversity values obtained for the survey as a whole were 4.42 nats (H') and 0.85 (J'). Mean number of species per plot was 20.7, and minimum and maximum values were six (Mag) and 41 species (Rg). The highest values of floristic similarity were found between the well-drained rocky and dry grasslands (Tab. 4). On the other hand, moderately-drained and poorly-drained communities (Mog and Mag) obtained distinct resemblance values. While moist grasslands registered similarity values ranging between 40 and 50% considering the well-drained areas, marshy grasslands obtained lower values when compared to all other communities. Despite the higher species richness found in dry grasslands, the highest diversity indexes were registered at rocky grasslands, which also presented highest family richness, total exclusive families and mean number of species per plot (Tab. 5). Generally speaking, dry grasslands present the highest species richness considering the most expressive families in our survey. Marshy grasslands, on the other hand, presented a larger proportion of exclusive species (56%), despite the lower richness and diversity values in comparison to the remaining communities, and the predominance of the families Poaceae and Cyperaceae.

The analysis of floristic similarity between our study and three other phytosociological surveys of grassland vegetation at Porto Alegre's granitic hills (Boldrini *et al.* 1998; Overbeck *et al.* 2006; Ferreira *et al.* 2010) registered similar values (ca. 27%) in all pairwise comparisons. A list of the 37 common species registered in the four studies is presented in Appendix 4. Families with highest number of shared species among the hills were once again Poaceae (12), Asteraceae (10) and Fabaceae (4), highlighting the shared herbaceous and shrub species with high frequency and/or cover in the composition of the regional grassland vegetation.

Discussion

Floristic and phytosociological surveys of the grassland vegetation present at the chain of granitic hills of Porto Alegre indicate the occurrence of ecosystems with high species richness. Overbeck *et al.* (2006) and Setubal & Boldrini (2010) registered the occurrence of ca. 500 species at Morro Santana (220 ha) and Morro São Pedro (440 ha), respectively. Ferreira et al. (2010) registered diversity indexes of 4.51 nats (H') and 0.86 (J') in the grasslands at Morro do Osso, which were very similar to the ones found in our study. Preliminary evaluations regarding a complete checklist of the grassland species that occur in Porto Alegre municipality point out 737 species (Setubal *et al.*, in press), which represents ca. 35% of the 2.150 grassland species registered in the Pampa biome in RS state (I.I. Boldrini, personal communication). Total numbers of mosses and ferns that occur in the grasslands of the same region remain unknown. The high number of species coupled with the small area this vegetation occupies in Porto Alegre (7.43% according to Hasenack *et al.* 2008) characterizes environments with high plant diversity, currently isolated in islands at hilltops due to the occupation of forests in hillsides and surrounding plains, and they are insufficiently represented in local conservation units (only 0.45%) (Setubal & Boldrini 2010). In spite of the lack of studies that point out the percent contribution of the local species' phytogeographic origin, dominant species present estival behavior, being derived from the altitude grasslands at northern RS state (Brazilian Rainforest biome). However, the occurrence of endemism of pampean species in the hills of the

Table 5 — Distribution of families and respective number of species in four communities evaluated in the sampling of the grassland vegetation at *Morro São Pedro*, Porto Alegre municipality, RS state, Brazil. Rg = rocky grassland; Dg = dry grassland; Mog = moist grassland; Mag = marshy grassland.

Families	Rg	Dg	Mog	Mag	Species number
Acanthaceae	0	0	1	0	1
Alstroemeriaceae	1	1	0	0	1
Amaranthaceae	2	1	1	0	2
Anacardiaceae	0	1	0	0	1
Apiaceae	8	7	4	0	10
Apocynaceae	1	1	0	0	1
Araliaceae	1	0	1	0	1
Asteraceae	29	31	22	1	39
Bromeliaceae	1	1	1	0	1
Cactaceae	1	0	0	0	1
Celastraceae	1	0	0	0	1
Convolvulaceae	1	1	1	0	3
Cyperaceae	5	7	5	4	12
Droseraceae	0	0	1	0	1
Euphorbiaceae	3	3	1	0	3
Fabaceae	18	19	7	1	22
Hypoxidaceae	0	1	1	0	1
Iridaceae	5	5	4	0	6
Juncaceae	0	0	0	1	1
Lamiaceae	1	1	1	0	1
Linaceae	1	0	0	0	1
Malvaceae	3	5	1	0	5
Melastomataceae	1	1	1	1	2
Myrtaceae	1	1	0	0	1
Orchidaceae	1	1	1	0	2
Oxalidaceae	1	1	1	1	2
Poaceae	23	30	23	7	34
Polygalaceae	1	3	4	0	4
Rubiaceae	8	7	3	0	8
Smilacaceae	1	0	1	0	1
Solanaceae	2	1	0	0	2
Verbenaceae	3	5	3	0	6
Number of exclusive families	3	1	2	1	
Totals	27	24	22	7	177

region (Ferreira 2010), points out the occurrence of transitional ecosystems between the two biomes, fact that still demands further evaluation.

The sociological behavior registered between the two groups shaped by the six most expressive families in the survey (i.e., with predominance in species' cover or frequency values) reflect the general pattern of heterogeneity and diversity of the studied grassland vegetation. While a small number of species with high cover values represents the larger portion of plant biomass in these grasslands, highly frequent species, but with low cover values, are intermingled in the vegetation matrix, contributing to increase diversity. The occurrence of a large number of rare and intermediately-frequent species significantly increases diversity, resulting in the elevated patterns of species richness presently found in these grasslands.

The recurrence of periodical burning events, in intervals of 2–3 years in the study area (I.I. Boldrini, personal observation), also common in other granitic hills at the region (Overbeck *et al.* 2005), could be a key factor associated to the maintenance of diversity in these grasslands, since grazing activity is low in the region. Ferreira *et al.* (2010) concluded that a recent burning event in the grasslands of Morro do Osso contributed to the reduction of dominance of cespitose grasses, allowing rare species to establish and raising overall equability. According to Overbeck *et al.* (2005), after this diversity peak, in the intermediate to long-term species composition tends to return to the former condition, that is, the domination of cespitose grasses. However, due to new burning events, this domination is not a stable state, resulting in the alternation of different successional stages in contiguous grassland patches, so that each stage is characterized by different groups of species and development stages, contributing to raise diversity. Besides that, burning events also slow down the advance of forest vegetation over grasslands (Muller *et al.* 2007).

The low explanation in both axes obtained in the ordination analysis is probably related to the large number of variables registered in the survey, especially species with low cover and frequency values. Overbeck *et al.* (2006) found a similar problem when performing multivariate analyses in a composition and abundance data matrix with 170 species registered in sampling units placed along a gradient between forest borderlines and grasslands at Morro Santana. When data were condensed in twelve species groups (biological forms), the explanatory power of axes 1 and 2 raised from 13.8% and 11.0% to 46.7% and 20.7% respectively. Moreover, one needs to critically consider the influence of supposed distortions resulting from comparisons between data generated in sets with distinct number of sampling units per community used in this survey. This incompatibility is the result of natural conditions such as the natural area these communities occupy, with high predominance of dry areas and scarcity of moist areas, which hampers a uniform and representative sampling effort in each environment. However, we believe that the species-level evaluation we presented significantly contributes to a better comprehension of taxa's occupation and distribution patterns in the environment, unraveling patterns of similarity and floristic variability between and within the four sampled communities. For example, rocky grasslands and dry grasslands presented higher levels of dispersion and interface between their sampling units due to shared generalist species, whereas moist and marshy grasslands were grouped and with smaller dispersion area in the graphic, revealing environments with lower species richness and higher floristic exclusiveness. We believe to have fulfilled other important objectives to the advance of knowledge concerning this vegetation, such as documenting the occurrence of grasslands in moist environments at the regional hills and evaluating the significance of different communities as discrete and measurable floristic units, that may be comparatively analyzed at the species level, facts so far absent in vegetation surveys carried out in the region.

The analysis of indicator species was also satisfactory concerning a better characterization of the studied communities at Morro São Pedro. We chose a value of $p = 0.01$ aiming to exclude species with generalist behavior that did not help to recognize the habitats described in our study area and in other environmental sites present in the Pampa and Atlantic Rainforest biomes. Boldrini *et al.* (1998), in a study carried out at Morro da Polícia, Porto Alegre, verified positive relations between high altitude areas, with higher solar exposition (known for the occurrence of rock outcrops) with species such as *Axonopus suffultus*, *Axonopus siccus* (Nees) Kuhlm. and *T. montufarii*, all of which were rocky grasslands indicator species at Morro São Pedro. However, caution is needed when doing comparative evaluations, and further studies are needed concerning species' behavior to confirm their higher or lower exclusiveness in the occupation of similar habitats and to ultimately consider them as good indicator species. The evaluation of a larger cover and frequency database of south Brazilian grassland species in the intermediate and long-term may complement this knowledge.

The influence of environmental factors in species' distribution lead to structural variations among the different communities. The lowest diversity values obtained in dry, moist and marshy grasslands, which predominantly occupy areas with deeper soils, are the result of the high cover values of dominant cespitose grass species such as *S. albescens, S. tenerum* and *I. minus* respectively, which grant higher homogeneity and density to the vegetation due to large leaf biomass cover. In rocky grasslands, on the other hand, relief favors the occurrence of shallower soils (hilltops and upper hillsides), influencing lower values of vegetation height, which facilitates light entry, and lower competitive dominance of cespitose grasses. Another factor that probably contributes positively to a higher diversity in rocky grasslands is the presence of rocks of various sizes, which grants higher structural heterogeneity to the habitat, creating a higher number of ecological niches and attenuating the intensity of fire, thus allowing the occurrence of different juxtaposed succession stages and rising diversity and similarity indexes in these environments.

The larger proportion of species that are exclusive to moist environments, in comparison to dry areas, may be related to the hypothesis of the higher selectivity to colonization of these environments due to the occurrence of variable periods of hydric stress due to soil saturation. In marshy grasslands, the higher number of exclusive species and lower similarity in comparison to the remaining communities indicates that most of the regional species do not tolerate long periods of hydric stress, fact that restricts local species colonization in this environment. Thus, we hypothesize that the circular pattern, shaped as a gradient, obtained in the graphic generated through ordination analysis reflects groups that are predominantly influenced by environmental factors that define species' distribution patterns. We believe that the main local factors are hydromorphic levels, relief position and soil types that vary along topographic gradients, which could play the role of filters for colonization of these environments. The two first factors were considered by Focht & Pillar (2003) as preponderant for the comprehension of species distribution in a study of detailed vegetation ecology of a natural grassland area pertaining to the phytophysiognomy of the Campos do Centro do Estado (Boldrini 2009), relatively close to Porto Alegre region and with similar climatic conditions.

In spite of the low values of floristic similarity found among the different phytosociological studies carried out in the regional grassland vegetation, we suggest that they shape a floristic unit due to shared key species. Ferreira *et al.* (2010) have calculated floristic similarity values of ca. 33% between their study and two other phytosociologic surveys (Boldrini *et al.* 1998; Overbeck *et al.* 2006) carried out in the regional chain of granitic hills. The similarity value of ca. 27% calculated between Morro São Pedro and the three other studies, albeit low, confirms the 37 shared herbaceous and shrub species that are relatively frequent and with good participation in cover composition of the regional grassland vegetation. Besides the species registered in these four surveys, other common and rare species are also shared between two or more hills, fact already mentioned by Aguiar *et al.* (1986). Some factors that might be associated to the low values of similarity registered in the mentioned surveys may also be related to the difficulty to uniformly evaluate this vegetation due to its high richness of rare species (i.e., low-frequency species) and the use of different methods and sampling efforts in different phenological and successional stages of the vegetation. The larger distance and isolation between Morro São Pedro and the other hills that were already studied (Morro do Osso, Morro da Policia and Morro Santana), all of which are located in the central region of the municipality and connected by ridges, could possibly be responsible for the lower levels of similarity we found. Even considering species' distribution patterns that still need to be better interpreted, we believe that, besides the floristic unit, these grasslands share other features (e.g., similar groups of functional types of plants), since all previous surveys indicate similar structural features in the constitution of this vegetation. The occurrence of a similar anthropogenic management in all grassland-covered areas of the region also contributes to that, and represents a key aspect for the conservation of these formations that still demands further investigation, concomitantly with the establishment of Conservation Units that encompass the grassland-forest mosaic, due to its small area within the municipality. Besides that, the establishment of Conservation Units in grassland-covered areas must take into account long-term research that evaluate the use o burning practices for the conservation of grasslands and its efficiency as a maintaining agent of vegetation and its diversity. As pointed out by Nabinger *et al.* (2000), it is suggested that other conservationist management practices are comparatively studied in these researches, such as mowing and grazing with adequate animal density, aiming to evaluate costs and benefits of each treatment.

Acknowledgements

Thanks to Leda Charczuk Viana and Felipe C. Viana for supporting our field work; to CAPES (Coordenação de Aperfeiçoamento do Ensino Superior) for a scholarship granted to the first author; to the researching team at the Laboratório de Estudos em Vegetação Campestre (LEVCamp - UFRGS) for general support; to the Programa de Pós-Graduação em Botânica (UFRGS) for administrative support and physical infrastructure; and to Rodrigo Bergamim and Pedro Maria de Abreu Ferreira for collaboration in conducting the data analysis.

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Artigo recebido em 08/04/2011. Aceito para publicação em 02/10/2011.

Rodriguésia 63(3): A1-A13. 2012
http://rodriguesia.jbrj.gov.br

Phytosociology and natural subtropical grassland communities on a granitic hill in southern Brazil

Fitossociologia e comunidades de campos subtropicais naturais em um morro granítico no sul do Brasil

Robberson Bernal Setubal & Ilsi Iob Boldrini

Appendix 1 – Floristic and phytosociological list and communities distribution of the 177 species registered in 70 sampling units (1 x1 m) in the sampling of the grassland vegetation at Morro São Pedro, Porto Alegre municipality, RS state, Brazil, ordered by botanical families. FA = absolute frequency; FR = relative frequency; CA = absolute cover; CR = relative cover; IVI = importance value index. First 30 IVI-rated species in bold. Vouchers were deposited in the Herbarium ICN

Families / Species	Voucher	Rg	Dg	Mog	Mag	FA (%)	FR (%)	CA (%)	CR (%)	IVI (%)
ACANTHACEAE										
Ruellia brevicaulis (Nees) Lindau.	R. Setubal & I. Boldrini, 101			x		2.00	0.14	0.60	0.05	0.09
ALSTROEMERIACEAE										
Alstroemeria albescens M.C. Assis	R. Setubal & D. Fuhro, 201	x	x			4.00	0.28	2.00	0.16	0.22
AMARANTHACEAE										
Gomphrena graminea Moq.	R. Setubal, 99	x				2.00	0.14	1.00	0.08	0.11
Pfaffia tuberosa (Sprengel) Hicken	R. Setubal & A. Mello, 261	x	x	x		13.00	0.90	5.30	0.42	0.66
ANACARDIACEAE										
Schinus weinnmanifolius Engl.	R. Setubal *et al.*, 281		x			1.00	0.07	1.00	0.08	0.07
APIACEAE										
Cyclospermum leptophyllum (Pers.) Eichler	R. Setubal & A. Mello, 397		x	x		2.00	0.14	0.60	0.05	0.09
Eryngium balansae H. Wolff	R. Setubal *et al.*, 703	x				2.00	0.14	2.50	0.20	0.17
Eryngium ciliatum Cham. & Schltdl.	R. Setubal, 142	x	x			2.00	0.14	1.50	0.12	0.13
Eryngium elegans Cham. & Schltdl.	R. Setubal, 141		x	x		9.00	0.62	16.00	1.26	0.94
Eryngium eriophorum Cham. & Schltdl.	R. Setubal, 38	x				4.00	0.28	2.00	0.16	0.22
Eryngium horridum Malme	R. Setubal *et al.*, 277	x	x			4.00	0.28	5.50	0.43	0.36
Eryngium megapotamicum Malme	R. Setubal, 138	x				1.00	0.07	1.00	0.08	0.07
Eryngium paniculatum Cav. & Dombey ex F. Delaroche	R. Setubal & M. Grings, 39	x	x			2.00	0.14	1.00	0.08	0.11
***Eryngium pristis* Cham. & Schltdl.**	R. Setubal & J. Bassi, 36	x	x	x		41.00	2.83	92.00	7.26	5.04

Families / Species	Voucher	Rg	Dg	Mog	Mag	FA (%)	FR (%)	CA (%)	CR (%)	IVI (%)
***Eryngium sanguisorba* Cham. et. Schltdl.**	R. Setubal, 37	x	x	x		28.00	1.93	17.00	1.34	1.64
APOCYNACEAE										
Macrosiphonia longiflora (Desf.) Müll. Arg.	R. Setubal, 97	x	x			4.00	0.28	2.00	0.16	0.22
ARALIACEAE										
Hydrocotyle exigua Malme	R. Setubal & M. Grings, 645	x		x		4.00	0.28	2.10	0.17	0.22
ASTERACEAE										
Acmella bellidioides (Smith in Rees) R.K. Jansen	R. Setubal, 55	x	x	x		5.00	0.35	2.10	0.17	0.26
***Aspilia montevidensis* (Spreng.) Kuntze**	R. Setubal, 56	x	x	x		47.00	3.25	31.00	2.44	2.85
Baccharis articulata (Lam.) Pers.	R. Setubal & G. Seger, 156	x	x			5.00	0.35	3.50	0.28	0.31
***Baccharis cognata* DC.**	R. Setubal, 22	x	x	x		25.00	1.73	28.10	2.22	1.97
Baccharis crispa Spreng.	R. Setubal, 155		x			2.00	0.14	2.50	0.20	0.17
Baccharis incisa Hook. & Arn.	R. Setubal, 68		x			1.00	0.07	1.00	0.08	0.07
Baccharis ochracea Spreng.	R. Setubal *et al.*, 65	x	x	x		4.00	0.28	3.00	0.24	0.26
Baccharis pentodonta Malme	R. Setubal, 19	x				2.00	0.14	1.00	0.08	0.11
Baccharis sessiliflora Vahl.	R. Setubal, 749	x				3.00	0.21	3.00	0.24	0.22
Baccharis subopposita DC.	R. Setubal, 157	x	x			5.00	0.35	10.00	0.79	0.57
Calea cymosa Less.	R. Setubal *et al.*, 103	x				2.00	0.14	1.00	0.08	0.11
Calea uniflora Less.	R. Setubal, 53	x	x	x		10.00	0.69	5.50	0.43	0.56
Chaptalia integerrima (Vell.) Burkart	R. Setubal & J. Bassi, 51	x	x	x		9.00	0.62	5.00	0.39	0.51
Chaptalia piloselloides (Vahl) Baker	R. Setubal, 752	x	x	x		15.00	1.04	7.50	0.59	0.81
***Chromolaena congesta* (Hook. & Arn.) R.M. King & H. Rob.**	R. Setubal & M. Grings, 110	x	x	x		33.00	2.28	16.10	1.27	1.77
Chromolaena laevigata (Lam.) R.M. King & H. Rob.	R. Setubal, 123		x			2.00	0.14	1.00	0.08	0.11
Chromolaena verbenacea (DC.) R.M. King & H. Rob.	R. Setubal, 186		x	x		6.00	0.41	4.00	0.32	0.36
***Chrysolaena flexuosa* (Sims) H.Rob.**	R. Setubal, 62	x	x	x		42.00	2.90	23.00	1.81	2.36
Criscia stricta (Spreng.) Katinas	R. Setubal & J. Bassi, 49		x	x		2.00	0.14	1.00	0.08	0.11

Families / Species	Voucher	Rg	Dg	Mog	Mag	FA (%)	FR (%)	CA (%)	CR (%)	IVI (%)
***Disynaphia ligulifolia* (Hook. & Arn.) R.M. King & H. Rob.**	R. Setubal *et al.*, 132	x	x	x		21.00	1.45	30.10	2.37	1.91
Eclipta megapotamica (Spreng.) Sch. Bip. ex S.F. Blake	R. Setubal, 347				x	3.00	0.21	1.50	0.12	0.16
Eupatorium hirsutum Hook. & Arn.	R. Setubal *et al.*, 159	x	x			8.00	0.55	4.00	0.32	0.43
Grazielia intermedia (DC.) R.M. King & H. Rob.	R. Setubal, 114	x				1.00	0.07	2.00	0.16	0.11
Gyptis pinnatifida Cass.	R. Setubal & G. Seger, 187	x				3.00	0.21	3.00	0.24	0.22
Heterothalamus psiadioides Less.	R. Setubal & J. Bassi, 45			x		2.00	0.14	0.60	0.05	0.09
Isostigma peucedanifolium (Spreng.) Less.	R. Setubal & M. Grings, 213	x	x	x		3.00	0.21	1.50	0.12	0.16
Lucilia acutifolia (Poir.) Cass.	R. Setubal & M. Grings, 214	x	x	x		7.00	0.48	2.30	0.18	0.33
Lucilia nitens Less.	R. Setubal & M. Grings, 215	x	x	x		6.00	0.41	2.60	0.21	0.31
Mikania fulva (Hook. & Arn.) Baker	R. Setubal & M. Grings, 216		x	x		3.00	0.21	1.50	0.12	0.16
Orthopappus angustifolius (Sw.) Gleason	R. Setubal *et al.*, 108	x	x			6.00	0.41	3.50	0.28	0.35
Pterocaulon angustifolium DC.	R. Setubal *et al.*, 106	x	x			3.00	0.21	1.50	0.12	0.16
Schlechtendalia luzulifolia Less.	R. Setubal, 105	x	x	x		7.00	0.48	14.00	1.10	0.79
Stenachaenium campestre Baker	R. Setubal, 761		x			1.00	0.07	1.00	0.08	0.07
Trixis nobilis (Vell.) Katinas	R. Setubal & M. Grings, 442	x				1.00	0.07	1.00	0.08	0.07
Stenocephalum megapotamicum (Spreng.) Sch. Bip.	R. Setubal, 61		x	x		2.00	0.14	1.00	0.08	0.11
Stomatanthes oblongifolius (Spreng.) H. Rob.	R. Setubal *et al.*, 139	x	x			2.00	0.14	1.00	0.08	0.11
Vernonanthura nudiflora (Less.) H. Rob.	R. Setubal & J. Cabral, 58	x	x	x		13.00	0.90	6.70	0.53	0.71
Vernonia squarrosa (D. Don) Less.	R. Setubal, 437	x	x			3.00	0.21	1.10	0.09	0.15
Viguiera immarginata (DC.) Herter	R. Setubal & M. Grings, 223	x	x	x		3.00	0.21	1.50	0.12	0.16
BROMELIACEAE										
Dyckia leptostachya Baker	R. Setubal & J. Bassi, 367	x	x			5.00	0.35	7.00	0.55	0.45
CACTACEAE										
Parodia ottonis (Lehm.) N.P. Taylor	R. Setubal, 363	x				4.00	0.28	2.00	0.16	0.22

Families / Species	Voucher	Rg	Dg	Mog	Mag	FA (%)	FR (%)	CA (%)	CR (%)	IVI (%)
CELASTRACEAE										
Maytenus cassineformis Reissek	R. Setubal, 866	x				1.00	0.07	1.00	0.08	0.07
CONVOLVULACEAE										
Cuscuta sp.	R. Setubal & J. Cabral, 340	x	x	x		5.00	0.35	1.70	0.13	0.24
Dichondra sericea Sw.	R. Setubal & M. Grings, 644	x	x			2.00	0.14	2.50	0.20	0.17
Evolvulus sericeus Sw.	R. Setubal, 342	x	x	x		20.00	1.38	4.80	0.38	0.88
CYPERACEAE										
Bulbostylis juncoides (Vahl) Kük. ex Osten	R. Setubal & I. Boldrini, 33	x	x			4.00	0.28	4.00	0.32	0.30
Bulbostylis subtilis M.G. López	R. Setubal, 766	x	x	x		5.00	0.35	2.50	0.20	0.27
Carex phalaroides Kunth	R. Setubal, 769	x		x		2.00	0.14	1.00	0.08	0.11
Cyperus aggregatus (Willd.) Endl.	R. Setubal, 32		x			3.00	0.21	1.50	0.12	0.16
Cyperus haspan L. var. *haspan*	R. Setubal, 30				x	1.00	0.07	2.00	0.16	0.11
Eleocharis nudipes (Kunth) Palla	R. Setubal & J. Bassi, 26				x	1.00	0.07	8.00	0.63	0.35
***Rhynchospora barrosiana* Guagl.**	R. Setubal, 781		x	x	x	13.00	0.90	15.00	1.18	1.04
Rhynchospora emaciata (Nees) Boeckeler	R. Setubal, 18			x		2.00	0.14	1.00	0.08	0.11
Rhynchospora holoschoenoides (Rich.) Herter	R. Setubal, 783				x	1.00	0.07	2.00	0.16	0.11
Rhynchospora rugosa (Vahl) Gale	R. Setubal & A. Mello, 24	x	x			8.00	0.55	4.00	0.32	0.43
Rhynchospora setigera Griseb.	R. Setubal, 17	x	x			7.00	0.48	4.00	0.32	0.40
***Scleria balansae* Maury**	R. Setubal, 784		x	x		24.00	1.66	32.00	2.52	2.09
DROSERACEAE										
Drosera brevifolia Pursh	R. Setubal, 334			x		2.00	0.14	2.50	0.20	0.17
EUPHORBIACEAE										
Bernardia multicaulis Müll. Arg.	R. Setubal, 786	x	x	x		6.00	0.41	2.60	0.21	0.31
Croton lanatus var. *astrogynus* (Baill.) P.E. Berry	R. Setubal & A. Mello, 337	x	x			7.00	0.48	4.00	0.32	0.40
Euphorbia selloi (Klotzsch & Garcke) Boiss.	R. Setubal, 338	x	x			11.00	0.76	1.90	0.15	0.45
FABACEAE										
***Centrosema virginianum* (L.) Benth.**	R. Setubal, 161	x	x	x		19.00	1.31	10.00	0.79	1.05

Families / Species	Voucher	Rg	Dg	Mog	Mag	FA (%)	FR (%)	CA (%)	CR (%)	IVI (%)
***Collaea stenophylla* (Hook. & Arn.) Benth.**	R. Setubal, 163	x	x	x		27.00	1.86	16.50	1.30	1.58
Crotalaria tweediana Benth.	R. Setubal & I. Boldrini, 165	x	x			6.00	0.41	3.50	0.28	0.35
***Desmanthus virgatus* (L.) Willd.**	R. Setubal & J. Bassi, 166	x	x	x		29.00	2.00	12.10	0.95	1.48
Desmodium adscendens (Sw.) DC.	R. Setubal & J. Bassi, 167				x	1.00	0.07	3.00	0.24	0.15
Desmodium cuneatum Hook. & Arn.	R. Setubal, 168		x	x		2.00	0.14	1.00	0.08	0.11
Desmodium incanum DC.	R. Setubal & J. Bassi, 169	x	x			3.00	0.21	1.10	0.09	0.15
Eriosema tacuaremboense Arechav.	R. Setubal, 170	x	x			6.00	0.41	2.60	0.21	0.31
Galactia gracillima Benth.	R. Setubal, 791	x				2.00	0.14	0.60	0.05	0.09
Galactia neesii var. *australis* Malme	R. Setubal & A. Mello, 171	x	x	x		9.00	0.62	5.50	0.43	0.53
Galactia pretiosa Burkart	R. Setubal, 172	x	x	x		16.00	1.10	5.60	0.44	0.77
***Macroptilium prostratum* (Benth.) Urb.**	R. Setubal, 176	x	x			19.00	1.31	9.50	0.75	1.03
Mimosa acerba Benth.	R. Setubal, 459	x	x			11.00	0.76	6.20	0.49	0.62
Mimosa cruenta Benth. var. cruenta	R. Setubal, 440	x		x		3.00	0.21	4.00	0.32	0.26
Mimosa daleoides Benth.	R. Setubal & G. Seger, 479		x			1.00	0.07	2.00	0.16	0.11
Mimosa dolens subsp. *rigida* (Benth.) Barneby	R. Setubal, 793	x	x			7.00	0.48	3.50	0.28	0.38
Mimosa parvipinna Benth.	R. Setubal & M. Grings, 466	x	x			3.00	0.21	1.50	0.12	0.16
Poiretia tetraphylla (Poir.) Burkart	R. Setubal & M. Grings, 177		x	x		2.00	0.14	1.00	0.08	0.11
Rhynchosia corylifolia Mart. ex Benth.	R. Setubal, 178	x	x			12.00	0.83	10.00	0.79	0.81
Rhynchosia diversifolia Micheli	R. Setubal & J. Bassi, 179	x	x			12.00	0.83	5.60	0.44	0.64
Rhynchosia hauthalli (Kuntze) Grear	R. Setubal & A. Mello, 180	x	x			2.00	0.14	1.00	0.08	0.11
Rhynchosia lateritia Burkart	R. Setubal, 796	x	x			6.00	0.41	7.50	0.59	0.50
HYPOXIDACEAE										
Hypoxis decumbens L.	R. Setubal, 385		x	x		2.00	0.14	1.10	0.09	0.11
IRIDACEAE										
Gelasine elongata (Graham) Ravenna	R. Setubal, 120	x		x		2.00	0.14	0.60	0.05	0.09
Herbertia pulchella Sweet	R. Setubal & M. S. Rigo, 741	x	x	x		13.00	0.90	5.70	0.45	0.67
Sisyrinchium micranthum Cav.	R. Setubal & A. Mello, 119	x	x			5.00	0.35	1.30	0.10	0.22

Families / Species	Voucher	Rg	Dg	Mog	Mag	FA (%)	FR (%)	CA (%)	CR (%)	IVI (%)
***Sisyrinchium palmifolium* L.**	R. Setubal, 126	x	x	x		28.00	1.93	18.50	1.46	1.70
Sisyrinchium vaginatum Spreng.	R. Setubal, 129	x	x	x		20.00	1.38	6.10	0.48	0.93
Trimezia spathata (Baker) Ravenna	R. Setubal, 130		x			2.00	0.14	1.50	0.12	0.13
JUNCACEAE										
Juncus microcephalus Kunth	R. Setubal & A. Mello, 383				x	3.00	0.21	6.00	0.47	0.34
LAMIACEAE										
Glechon ciliata Benth.	R. Setubal, 372	x	x	x		16.00	1.10	8.50	0.67	0.89
LINACEAE										
Linum burkartii Mildner	R. Setubal, 805	x				1.00	0.07	1.00	0.08	0.07
MALVACEAE										
Abutilon malachroides A. St.-Hil. & Naudin	R. Setubal & A. Mello, 81		x			4.00	0.28	2.00	0.16	0.22
Krapovickasia urticifolia (A. St.-Hil.) Fryxell	R. Setubal, 84	x	x			3.00	0.21	0.70	0.06	0.13
Pavonia friesii Krapov.	R. Setubal & G. Seger, 83	x	x			5.00	0.35	2.50	0.20	0.27
Sida regnellii R.E. Fr.	R. Setubal, 806		x			2.00	0.14	0.60	0.05	0.09
Wissadula glechomatifolia (St. Hil.) R. E. Fries	R. Setubal & A. Mello, 87	x	x	x		18.00	1.24	8.30	0.65	0.95
MELASTOMATACEAE										
Tibouchina gracilis (Bonpl.) Cogn.	R. Setubal, 262	x	x	x		12.00	0.83	7.10	0.56	0.69
Tibouchina urbanii Cogn.	R. Setubal, 467				x	3.00	0.21	2.00	0.16	0.18
MYRTACEAE										
Eugenia dimorpha O. Berg	R. Setubal & M. S. Rigo, 689	x	x			3.00	0.21	2.50	0.20	0.20
ORCHIDACEAE										
Habenaria edwallii Cogn.	R. Setubal, 811			x		1.00	0.07	2.00	0.16	0.11
Liparis vexillifera (Lex.) Cogn.	R. Setubal, 92	x	x			2.00	0.14	1.00	0.08	0.11
OXALIDACEAE										
Oxalis bipartita A. St.-Hil.	R. Setubal & G. Seger, 353			x	x	4.00	0.28	2.50	0.20	0.24
Oxalis brasiliensis G. Lodd.	R. Setubal, 354	x	x			8.00	0.55	2.40	0.19	0.37
POACEAE										
***Andropogon lateralis* Nees**	R. Setubal, 225	x	x	x	x	30.00	2.07	32.50	2.56	2.32

Families / Species	Voucher	Rg	Dg	Mog	Mag	FA (%)	FR (%)	CA (%)	CR (%)	IVI (%)
Andropogon macrothrix Trin.	R. Setubal & I. Boldrini, 432			x		4.00	0.28	3.00	0.24	0.26
Aristida filifolia (Arechav.) Herter	R. Setubal & I. Boldrini, 680	x	x			6.00	0.41	8.00	0.63	0.52
Aristida flaccida Trin. & Rupr.	R. Setubal & I. Boldrini, 694		x			6.00	0.41	7.00	0.55	0.48
Aristida laevis (Nees) Kunth	R. Setubal, 681	x	x	x		12.00	0.83	13.50	1.06	0.95
***Axonopus siccus* (Nees) Kuhlm.**	R. Setubal *et al.*, 679	x	x	x		10.00	0.69	16.00	1.26	0.98
***Axonopus suffultus* (Mikan ex Trin.) Parodi**	R. Setubal *et al.*, 230	x	x	x		20.00	1.38	27.50	2.17	1.78
Chascolytrum subaristatum (Lam.) Desv.	R. Setubal, 672	x	x	x		17.00	1.17	8.50	0.67	0.92
***Chascolytrum uniolae* (Nees) Essi, Longhi-Wagner & Souza-Chies**	R. Setubal & J. Bassi, 673	x	x	x		18.00	1.24	10.00	0.79	1.02
Danthonia cirrata Hack. & Arechav.	R. Setubal, 232		x			3.00	0.21	2.00	0.16	0.18
***Dichanthelium sabulorum* (Lam.) Gould. & C.A. Clark**	R. Setubal, 626	x	x	x	x	24.00	1.66	16.00	1.26	1.46
Elionurus muticus (Spreng.) Kuntze	R. Setubal, 235	x	x	x		16.00	1.10	17.00	1.34	1.22
Eustachys uliginosa (Hack.) Herter	R. Setubal, 684	x		x		4.00	0.28	4.50	0.35	0.32
***Gymnopogon burchellii* (Munro ex Doell) Ekman**	R. Setubal & G. Seger, 241	x	x	x		27.00	1.86	18.70	1.47	1.67
***Ischaemum minus* J. Presl**	R. Setubal & A. Mello, 668				x	5.00	0.35	40.00	3.15	1.75
Melica brasiliana Ard.	R. Setubal & G. Seger, 666		x			3.00	0.21	1.50	0.12	0.16
Panicum olyroides Kunth var. *olyroides*	R. Setubal, 614	x	x	x		12.00	0.83	13.00	1.03	0.93
Paspalum ionanthum Chase	R. Setubal & A. Mello, 189		x	x		3.00	0.21	5.00	0.39	0.30
Paspalum maculosum Trin.	R. Setubal, 191		x	x		7.00	0.48	12.00	0.95	0.71
***Paspalum plicatulum* Michx.**	R. Setubal, 193	x	x	x	x	27.00	1.86	22.50	1.77	1.82
Paspalum urvillei Steud.	R. Setubal & M. Grings, 194				x	1.00	0.07	2.00	0.16	0.11
Piptochaetium montevidense (Spreng.) Parodi	R. Setubal & J. Bassi, 663	x	x	x		7.00	0.48	5.00	0.39	0.44
***Saccharum villosum* Steud.**	R. Setubal, 248	x	x	x	x	10.00	0.69	16.50	1.30	1.00
Schizachyrium imberbe (Hack.) A. Camus	R. Setubal & I. Boldrini, 701	x	x			8.00	0.55	9.50	0.75	0.65
***Schizachyrium tenerum* Nees**	R. Setubal *et al.*, 249	x	x	x	x	17.00	1.17	36.10	2.85	2.01

Families / Species	Voucher	Rg	Dg	Mog	Mag	FA (%)	FR (%)	CA (%)	CR (%)	IVI (%)
Setaria parviflora (Poir.) Kerguélen	R. Setubal & A. Mello, 661		x	x		4.00	0.28	1.20	0.09	0.19
Setaria vaginata Spreng.	R. Setubal & A. Mello, 660	x	x	x		7.00	0.48	4.10	0.32	0.40
***Sorghastrum albescens* (E. Fourn.) Beetle**	R. Setubal, 254	x	x	x		39.00	2.69	106.00	8.36	5.53
Sporobolus indicus (L.) R. Br.	R. Setubal & I. Boldrini, 659		x			1.00	0.07	1.00	0.08	0.07
Stipa filiculmis Delile	R. Setubal, 196	x	x			3.00	0.21	10.00	0.79	0.50
***Stipa melanosperma* J. Presl.**	R. Setubal, 197	x	x			17.00	1.17	14.50	1.14	1.16
Stipa nutans Hack.	R. Setubal & I. Boldrini, 199		x	x		11.00	0.76	12.50	0.99	0.87
Trachypogon montufarii* (Kunth) Nees var. *montufarii	R. Setubal & I. Boldrini, 257	x	x			9.00	0.62	17.00	1.34	0.98
***Trachypogon montufarii* var. *mollis* (Nees) Andersson**	R. Setubal, 825	x	x	x		14.00	0.97	13.50	1.06	1.02
POLYGALACEAE										
Monnina oblongifolia Arechav.	R. Setubal, 116	x	x	x		16.00	1.10	10.20	0.80	0.96
Polygala brasiliensis L.	R. Setubal & A. Mello, 112			x		5.00	0.35	1.70	0.13	0.24
Polygala extraaxillaris Chodat	R. Setubal, 111		x	x		3.00	0.21	1.50	0.12	0.16
Polygala molluginifolia A. St.-Hil. & Moq.	R. Setubal & G. Seger, 115		x	x		2.00	0.14	0.60	0.05	0.09
RUBIACEAE										
Galianthe fastigiata Griseb.	R. Setubal, 146	x	x	x		18.00	1.24	7.00	0.55	0.90
Galium hirtum Lam.	R. Setubal & M. Grings, 687	x				2.00	0.14	1.00	0.08	0.11
Galium humile Cham. & Schltdl.	R. Setubal, 830	x	x	x		5.00	0.35	2.10	0.17	0.26
Galium megapotamicum (Spreng.) Ehrend.	R. Setubal & M. Grings, 686	x	x	x		8.00	0.55	4.80	0.38	0.47
Galium richardianum (Gillies ex Hook. & Arn.) Hicken	R. Setubal, 831	x	x			12.00	0.83	1.60	0.13	0.48
Richardia grandiflora (Cham. & Schltdl.) Steud.	R. Setubal, 145	x	x			12.00	0.83	6.00	0.47	0.65
Spermacoce capitata Ruiz & Pav.	R. Setubal, 134	x	x			4.00	0.28	1.60	0.13	0.20
Spermacoce verticillata (L.) G. Mey	R. Setubal & J. Bassi, 131	x	x			2.00	0.14	1.00	0.08	0.11
SMILACACEAE										
Smilax campestris Griseb.	R. Setubal & J. Bassi, 360	x		x		2.00	0.14	1.00	0.08	0.11

Families / Species	Voucher	Rg	Dg	Mog	Mag	FA (%)	FR (%)	CA (%)	CR (%)	IVI (%)
SOLANACEAE										
Calibrachoa excellens R. E. Fries	R. Setubal, 835	x				1.00	0.07	1.00	0.08	0.07
Calibrachoa ovalifolia (Miers) Stehmann & Semir	R. Setubal, 836	x	x			3.00	0.21	1.50	0.12	0.16
VERBENACEAE										
Glandularia marrubioides (Cham.) Tronc.	R. Setubal, 447	x	x			5.00	0.35	1.70	0.13	0.24
Glandularia thymoides (Cham.) N. O'Leary	R. Setubal, 394		x	x		4.00	0.28	2.00	0.16	0.22
Lantana montevidensis (Spreng.) Briq.	R. Setubal & J. Bassi, 390	x	x			3.00	0.21	2.50	0.20	0.20
Lippia aff. *pusila*	R. Setubal & M. Grings, 616		x			3.00	0.21	2.00	0.16	0.18
Lippia hieracifolia Cham.	R. Setubal, 393	x		x		2.00	0.14	1.00	0.08	0.11
Verbena intermedia Gillies & Hook. ex Hook.	R. Setubal, 604		x	x		2.00	0.14	1.00	0.08	0.11
Totals		**126**	**137**	**89**	**16**	**1448.00**	**100.00**	**1267.90**	**100.00**	**100.00**

Appendix 2 – List of 16 indicator species from four grassland communities at Morro São Pedro, Porto Alegre municipality, RS, based on the calculation of phytosociological parameters per community and analysis of indicator species (p = 0.05). FA = absolute frequency; FR = relative frequency; CA = absolute cover; CR = relative cover; IVI importance value index.

Families	Species	FA (%)	FR (%)	CA (%)	CR (%)	IVI (%)	p (%)
ROCKY GRASSLANDS							
Poaceae	*Axonopus suffultus* (Mikan ex Trin.) Parodi	11.00	2.74	16.00	5.05	3.89	0.008
Poaceae	*Axonopus siccus* (Nees) Kuhlm.	7.00	1.74	14.00	4.42	3.08	0.01
Poaceae	*Trachypogon montufarii* (Kunth) Nees var. *montufarii*	7.00	1.74	13.50	4.26	3.00	0.009
Poaceae	*Schizachyrium imberbe* (Hack.) A. Camus	7.00	1.74	9.00	2.84	2.29	0.01
DRY GRASSLANDS							
Poaceae	*Stipa melanosperma* J. Presl.	15.00	2.06	13.00	2.19	2.12	0.01
MOIST GRASSLANDS							
Cyperaceae	*Scleria balansae* Maury	13.00	4.66	25.00	8.98	6.82	0.001
Apiaceae	*Eryngium elegans* Cham. & Schltdl.	7.00	2.51	13.50	4.85	3.68	0.005
Cyperaceae	*Rhynchospora barrosiana* Guagl.	8.00	2.87	12.50	4.49	3.68	0.01
Poaceae	*Stipa nutans* Hack.	9.00	3.23	11.50	4.13	3.68	0.003
Iridaceae	*Sisyrinchium vaginatum* Spreng.	12.00	4.30	4.90	1.76	3.03	0.001
Poaceae	*Paspalum maculosum* Trin.	5.00	1.79	10.50	3.77	2.78	0.01
Asteraceae	*Chaptalia piloselloides* (Vahl) Baker	8.00	2.87	4.00	1.44	2.15	0.009
Asteraceae	*Chromolaena verbenacea* (DC.) R.M. King & H. Rob.	5.00	1.79	3.50	1.26	1.52	0.01
Polygalaceae	*Polygala brasiliensis* L.	5.00	1.79	1.70	0.61	1.20	0.006
MARSHY GRASSLANDS							
Poaceae	*Ischaemum minus* J. Presl	5.00	13.16	40.00	50.63	31.90	0.001
Juncaceae	*Juncus microcephalus* Kunth	3.00	7.89	6.00	7.59	7.74	0.001
Melastomataceae	*Tibouchina urbanii* Cogn.	3.00	7.89	2.00	2.53	5.21	0.001
Asteraceae	*Eclipta megapotamica* (Spreng.) Sch. Bip. ex S.F. Blake	3.00	7.89	1.50	1.90	4.90	0.001

Appendix 3 – List of the 16 species in decreasing IVI order registered in the four communities evaluated in the sampling of the grassland vegetation at Morro São Pedro, Porto Alegre municipality, RS. Brazil. Calculations carried out with the subsets of sampling units from each community. FA = absolute frequency; FR = relative frequency; CA = absolute cover; CR = relative cover; IVI = importance value index.

ROCKY GRASSLANDS				DRY GRASSLANDS			
Species	**FR (%)**	**CR (%)**	**IVI (%)**	**Species**	**FR (%)**	**CR (%)**	**IVI (%)**
Sorghastrum albescens (E. Fourn.) Beetle	3.16	13.06	8.11	*Eryngium pristis* Cham. & Schltdl.	2.99	9.78	6.38
Eryngium pristis Cham. & Schltdl.	3.84	9.61	6.72	*Axonopus suffultus* (Mikan ex Trin.) Parodi	2.74	5.05	3.89
Disynaphia ligulifolia (Hook. & Arn.) R.M. King & H. Rob.	2.19	4.21	3.20	*Andropogon lateralis* Nees	2.74	4.57	3.65
Chrysolaena flexuosa (Sims) H.Rob.	3.57	2.44	3.01	*Aspilia montevidensis* (Spreng.) Kuntze	3.48	2.68	3.08
Baccharis cognata DC.	2.47	3.37	2.92	*Axonopus siccus* (Nees) Kuhlm.	1.74	4.42	3.08
Aspilia montevidensis (Spreng.) Kuntze	3.02	2.44	2.73	*Trachypogon montufarii* (Kunth) Nees var. *montufarii*	1.74	4.26	3.00
Collaea stenophylla (Hook. & Arn.) Benth.	2.00	2.02	2.31	*Chromolaena congesta* (Hook. & Arn.) R.M. King & H. Rob.	2.99	1.77	2.38
Eryngium sanguisorba Cham. et. Schltdl.	2.47	1.85	2.16	*Schizachyrium imberbe* (Hack.) A. Camus	1.74	2.84	2.29
Desmanthus virgatus (L.) Willd.	2.88	1.43	2.16	*Paspalum plicatulum* Michx.	1.74	2.68	2.21
Gymnopogon burchellii (Munro ex Doell) Ekman	2.19	2.06	2.13	*Sorghastrum albescens* (E. Fourn.) Beetle	1.49	2.84	2.17
Stipa melanosperma J. Presl.	2.06	2.19	2.12	*Chrysolaena flexuosa* (Sims) H.Rob.	2.24	1.58	1.91
Elionurus muticus (Spreng.) Kuntze	1.65	2.53	2.09	*Trachypogon montufarii* var. *mollis* (Nees) Andersson	1.74	1.89	1.82
Chromolaena congesta (Hook. & Arn.) R.M. King & H. Rob.	2.33	1.43	1.88	*Dyckia leptostachya* Baker	1.00	2.05	1.52
Macroptilium prostratum (Benth.) Urb.	1.92	1.18	1.55	*Panicum olyroides* Kunth var. *olyroides*	1.00	1.73	1.36
Monnina oblongifolia Arechav.	1.78	1.30	1.54	*Galactia pretiosa* Burkart	1.99	0.63	1.31
Rhynchosia corylifolia Mart. ex Benth.	1.37	1.52	1.44	*Eryngium sanguisorba* Cham. et. Schltdl.	1.49	1.10	1.30

MOIST GRASSLANDS				MARSHY GRASSLANDS			
Species	**FR (%)**	**CR (%)**	**IVI (%)**	**Species**	**FR (%)**	**CR (%)**	**IVI (%)**
Scleria balansae Maury	4.66	8.98	6.82	*Ischaemum minus* J. Presl	13.16	50.63	31.90
Schizachyrium tenerum Nees	2.51	9.69	6.10	*Andropogon lateralis* Nees	13.16	5.06	9.11
Sorghastrum albescens (E. Fourn.) Beetle	3.58	7.00	5.29	*Dichanthelium sabulorum* (Lam.) Gould. & C.A. Clark	13.16	3.16	8.16
Eryngium elegans Cham. & Schltdl.	2.51	4.85	3.68	*Juncus microcephalus* Kunth	7.89	7.59	7.74
Rhynchospora barrosiana Guagl.	2.87	4.49	3.68	*Eleocharis nudipes* (Kunth) Palla	2.63	10.13	6.38
Stipa nutans Hack.	3.23	4.13	3.68	*Tibouchina urbanii* Cogn.	7.89	2.53	5.21
Saccharum villosum Steud.	2.51	4.67	3.59	*Paspalum plicatulum* Michx.	7.89	1.90	4.90
Aspilia montevidensis (Spreng.) Kuntze	3.94	2.87	3.41	*Rhynchospora barrosiana* Guagl.	7.89	1.90	4.90
Sisyrinchium palmifolium L.	3.23	3.23	3.23	*Eclipta megapotamica* (Spreng.) Sch. Bip. ex S.F. Blake	7.89	1.90	4.90
Sisyrinchium vaginatum Spreng.	4.30	1.76	3.03	*Desmodium adscendens* (Sw.) DC.	2.63	3.80	3.21
Paspalum maculosum Trin.	1.79	3.77	2.78	*Saccharum villosum* Steud.	2.63	2.53	2.58
Dichanthelium sabulorum (Lam.) Gould. & C.A. Clark	2.87	2.51	2.69	*Cyperus haspan* L. var. *haspan*	2.63	2.53	2.58
Paspalum plicatulum Michx.	2.51	2.51	2.51	*Paspalum urvillei* Steud.	2.63	2.53	2.58
Andropogon lateralis Nees	2.15	2.69	2.42	*Rhynchospora holoschoenoides* (Rich.) Herter	2.63	2.53	2.58
Chaptalia piloselloides (Vahl) Baker	2.87	1.44	2.15	*Schizachyrium tenerum* Nees	2.63	0.63	1.63
Gymnopogon burchellii (Munro ex Doell) Ekman	2.51	1.62	2.06	*Oxalis bipartita* A. St.-Hil.	2.63	0.63	1.63

Appendix 4 – List of the 37 common species among four phytosociological studies of grassland vegetation carried out in the chain of granitic hills at Porto Alegre municipality, RS, Brazil (Morro da Polícia - Boldrini *et al*. 1998; Morro Santana - Overbeck *et al*. 2006; Morro do Osso - Ferreira *et al*. 2010; Morro São Pedro).

Familie	**Species**
Anacardiaceae	*Schinus weinmannifolius* Engl.
Apiaceae	*Eryngium ciliatum* Cham. & Schltdl.
Apiaceae	*Eryngium horridum* Malme
Apiaceae	*Eryngium pristis* Cham. & Schltdl.
Asteraceae	*Aspilia montevidensis* (Spreng.) Kuntze
Asteraceae	*Baccharis articulata* (Lam.) Pers.
Asteraceae	*Baccharis crispa* Spreng.
Asteraceae	*Baccharis ochracea* Spreng.
Asteraceae	*Baccharis sessiliflora* Vahl
Asteraceae	*Calea uniflora* Less.
Asteraceae	*Disynaphia ligulifolia* (Hook. & Arn.) R.M. King & H. Rob.
Asteraceae	*Lucilia acutifolia* (Poir.) Cass.
Asteraceae	*Orthopappus angustifolius* (Sw.) Gleason
Asteraceae	*Vernonanthura nudiflora* (Less.) H. Rob.
Cactaceae	*Parodia ottonis* (Lehm.) N.P. Taylor
Cyperaceae	*Rhynchospora setigera* Griseb.
Euphorbiaceae	*Euphorbia selloi* (Klotzsch & Garcke) Boiss.
Fabaceae	*Centrosema virginianum* (L.) Benth.
Fabaceae	*Desmodium incanum* DC.
Fabaceae	*Macroptilium prostratum* (Benth.) Urb.
Fabaceae	*Rhynchosia diversifolia* Micheli
Poaceae	*Andropogon lateralis* Nees
Poaceae	*Aristida filifolia* (Arechav.) Herter
Poaceae	*Aristida flaccida* Trin. & Rupr.
Poaceae	*Aristida laevis* (Nees) Kunth
Poaceae	*Axonopus suffultus* (Mikan ex Trin.) Parodi
Poaceae	*Chascolytrum subaristatum* (Lam.) Desv.
Poaceae	*Chascolytrum uniolae* (Nees) Essi, Longhi-Wagner & Souza-Chie
Poaceae	*Dichanthelium sabulorum* (Lam.) Gould. & C.A. Clark
Poaceae	*Paspalum plicatulum* Michx.
Poaceae	*Piptochaetium montevidense* (Spreng.) Parodi
Poaceae	*Schizachyrium tenerum* Nees
Poaceae	*Trachypogon montufarii* (Kunth) Nees var. *montufarii*
Rubiaceae	*Galianthe fastigiata* Griseb.
Rubiaceae	*Richardia grandiflora* (Cham. & Schltdl.) Steud.
Rubiaceae	*Spermacoce verticillata* (L.) G. Mey
Verbenaceae	*Lantana montevidensis* (Spreng.) Briq.