Structure and composition of a grassland relict within an urban matrix: potential and challenges for conservation

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ABSTRACT – We investigated the vegetation composition and structure of a grassland relict in the area of the Botanical Garden of Porto Alegre, Rio Grande do Sul, Brazil. The area has remained without typical management (grazing or burning) for thirty years, but trees and shrubs have been removed periodically. In our floristic survey, we found 192 (morpho-) species. In the vegetation sampling, conducted in 30 plots of 1m², we found 140 (morpho-) species (mean per plot: 27), contrasting the hypothesis of species loss due to absence of grazing or fire. The dominant species were tussock grasses typical for rocky grasslands of the region. Five endangered species were found. The area presents a high conservation value and should be a considered a conservation priority in the Botanical Garden and the urban area of Porto Alegre. The biggest threats are shrub and tree encroachment and the invasion of *Pinus*. Options for the management of the area are discussed.

Keywords: campos sulinos, fragmentation, management, urban ecology

RESUMO – Estrutura e composição de um relicto de vegetação campestre em uma matriz urbana: potencial e desafios para a conservação. Investigamos a estrutura e composição da vegetação de um relicto de campo na área do Jardim Botânico de Porto Alegre, Rio Grande do Sul, Brasil. O único manejo efetuado, durante os últimos 30 anos foi a remoção periódica de árvores e arbustos. No levantamento florístico encontramos 192 (morfo-) espécies. Na amostragem da vegetação, realizado em 30 parcelas de 1m ², encontramos 140 (morfo-) espécies (média por parcela: 27), contrastando com a hipótese de perda de espécies devido à ausência de pastejo ou fogo. As espécies dominantes foram gramíneas cespitosas típicas de campos rupestres da região. Cinco espécies ameaçadas de extinção foram encontradas. A área apresenta um alto valor de conservação e deve ser considerada como prioritária pelo Jardim Botânico, e da área urbana de Porto Alegre. As maiores ameaças são o avanço de arbustos e árvores sobre o relicto bem como a invasão de *Pinus*. Opções para o manejo da área são discutidas.

Palavras-chaves: campos sulinos, fragmentação, manejo, ecologia urbana

INTRODUCTION

Recently, the biodiversity of urban areas has received considerable attention in ecological research, and "Urban Ecology" has become established as a research field of its own in Ecology (*e. g.* Niemelã *et al.*, 2011). In this context, the importance of urban green areas for biodiversity conservation has been recognized, including in ecosystems shaped by humans, and many cities have been shown to be hotspots of species diversity (*e. g.*, Pysek, 1993; Zerbe *et al.,* 2003). Green spaces prone to colonization by native species within large cities, such as parks or gardens, can represent large areas when compared to areas of environmental preservation. In the United Kingdom, residential gardens contain twice as much area than natural reserves (Chamberlain *et al.*, 2004) and remnants of native vegetation may constitute important refuges for native species. However, urban ecosystems are in close contact with manifold human activities and may suffer a number of anthropogenic pressures, such as higher disturbance frequency or more severe disturbances, pollution, or further fragmentation and its consequences on populations and ecological communities (*e. g.*, Lienert, 2004; Sushinsky *et al.*, 2013). On the other hand, green areas within the city may offer important ecosystem services, for example by contributing to the maintenance of air, soil and water quality and by offering access to biodiversity and allowing for aesthetic experiences to the urban population (*e. g.* Dobbs *et al.*, 2011; Lerman & Warren, 2011).

Most available studies of biodiversity conservation in urban areas come from the Northern Hemisphere, and while the importance of conservation action in urban areas of the Southern Hemisphere has been recognized at times (*e. g.* Adelmann *et al.*, 2011; Amaral *et al.*, 2012), few studies that can lay a basis for conservation are available. In the case of the city of Porto Alegre, capital of the Brazilian state Rio Grande do Sul, the high species richness of the forest-grassland mosaics on the granitic hills and their importance for nature conservation have been shown (Overbeck *et al.*, 2006; Behling *et al.*, 2007; Adelmann *et al.*, 2011; Setubal *et al.*, 2011). However, the question of active management, *e. g.*, conservation of grasslands by fire or grazing (Overbeck *et al.*, 2011), remains controversial even for these areas with proven high biodiversity, as it does even in conservation units in Rio Grande do Sul state (Pillar & Vélez, 2010).

In Porto Alegre, just as in other cities, not only large areas need to be in the focus of conservation action. Apart from the granitic hills and other large areas dominated by natural vegetation – such as the delta of the Jacuí River – a reasonable number of green spaces exists within the urban area of Porto Alegre, such as squares and parks, but only a few fragments of natural vegetation can be considered as more or less well preserved (Menegat, 2006). One of these fragments of natural vegetation can be found within the area of the Fundação Zoobotânica (FZB), a state center for biological studies and the site of Porto Alegre's Botanical Garden. This relict grassland and the surrounding forest patches, situated at the border of the Botanical Garden, can be considered an "island" of natural vegetation in the intensively managed green area. High plant species richness in the area and presence of endangered species had been shown in a floristic study conducted 25 years ago (Bueno & Martins, 1986). However, in this study, no characterization of vegetation structure and no assessment of the naturalness of the area had been made, and no studies were conducted since. While tree and shrub species are being removed periodically, the area is not under grazing or burning. The absence of this kind of management has been considered as problematic for the maintenance of biodiversity of South Brazilian grasslands (Overbeck *et al.*, 2007; Pillar & Vélez, 2010).

The aims of this study thus are to provide an analysis of floristic composition and structure of the grassland fragment, to discuss the floristic similarity with well-preserved grasslands in Porto Alegre and to initiate a discussion on potential and challenges of nature conservation in an urban context in general and specifically for the studied area within the Botanical Garden. As far as we know, no ecological study of a grassland area with a similar degree of fragmentation and isolation is available for southern Brazil, even less so in the urban context. We hypothesized that due to lack of typical management and of the isolated situation of the grassland fragment, plant diversity should be reduced in comparison to that of other grassland areas in Porto Alegre's granitic hills.

MATERIAL AND METHODS

Study area

Located at coordinates 30°03'14.27" S and 51°10'34.90" W, at an average altitude of 43 m and covering about 0.15 ha (1406.25 m²), a small area of grassland vegetation within the area of the Botanical Garden was kept preserved for scientific study since 1979 by the direction of the FZB (Bueno & Martins, 1986). The foundation performs periodic removal of pioneer tree and shrub species, both native and exotic, to ensure the maintenance of herbaceous vegetation (Lopes, 2004). The soil of the relict can be classified as Udorthent Dystrophic (according to Santos *et al.*, 2006). It is a mineral and shallow soil, with low base saturation, acidic pH (4.4 - 4.8) and high aluminum content (our own unpublished data from soil samples taken in the area).

Floristic study

We conducted a floristic survey in the area with visits approximately every two weeks, between September and November 2011. Species not immediately identified were collected for later identification. Endangered species were not collected. The principal tree and shrub species in the woody vegetation surrounding the grassland fragment were also identified.

Vegetation sampling

Vegetation was sampled in 30 sample units (SU) of 1 m², randomly arranged within the relict, with a minimum distance of 5 m from the edges of the fragment. Patches of vegetation with more than 50% coverage by shrubs or lianas were excluded, since the objective of this study was the characterization of grassland vegetation, not of the succession process. In each SU we recorded cover of each plant species found using visual estimates based on a scale of cover classes: less than 1%, 1-5%, 5-10%, 10-20%, 20-30% and so on. We also estimate cover of litter, rocks and bare soil. The survey was conducted during the second half of October, 2011. Plants that could not be identified in the field were collected and later identified by help of literature or experts. For the taxonomic classification, we used the APG III (2009) phylogenetic hypothesis. Nomenclature of grassland species follows the checklist by Boldrini *et al*. (in preparation). For all other species, we follow the Tropicos database (Tropicos 2013).

Data analysis

For each species we determined the absolute frequency (F), relative frequency (RF), average cover per plot (AC), relative cover (RC) and importance value (IV, defined as the sum of AC and RC divided by 2) (Müller-Dombois & Ellenberg, 1974). We used the Shannon index of entropy as the exponent of the equation e^H/S ('S' means number of taxa) to characterize the structure of vegetation in each plot. We estimated sample sufficiency with quadrate richness methods Chao 2 (Chao, 1987) and second-order jackknife (Smith & Belle, 1984), which are considered the most adequate methods b*y* Colwell & Coddington. (1994). The number of shared species between all combinations of plots and between the different hills was calculated using the software EstimateS 8.2 (Colwell, 2009). The list of species found in this study was compared to others from studies in the hills in Porto Alegre (Polícia hill, Boldrini *et al.*, 1998, Santana hill, Overbeck *et al.*, 2006, Osso hill, Ferreira *et al.*, 2010) by calculation of the Jaccard Index, using the software EstimateS 8.2.

RESULTS

Our floristic list contains 192 (morpho-) species, distributed among 48 families, 133 genera and 183 species. Nine records remained unidentified (3 of them non-native species), representing 95% of fully identified species. In the vegetation sampling, 40 families, 106 genera and 146 species were found in the 30 plots. Of these, eight records remained unidentified, representing 95% of fully identified species. The average number of species found per plot was 27 (min. 19 and max. 38) and the average evenness of the plots was 0.41, indicating no clear tendency of dominance by only a few taxa. According to both estimators used, the sampling effort was satisfactory (Chao 2, 96%, and jackknife 2, 89%). A complete species list with data from both surveys is shown in Table 1.

Cover of open soil was relatively high (16%), and average vegetation height was 22 cm. Considering the relative cover, grasses and graminoides were the most important (55%, mostly Poaceae), followed by other herbaceous species (mainly *Asteraceae*, *Apiaceae* and *Iridaceae*, 32%) and shrub species (*Asteraceae* and *Euphorbiaceae* families, 7%). The high contribution in our survey was remarkable (8% of the total vegetation cover); the species *Baccharis patens*, *Vernonanthura nudiflora* and *Eugenia dimorpha* being the most abundant. Some species typical of secondary succession are also present in our sample, *e. g. Allophylus edulis*, *Dodonea viscosa*, *Myrcia palustris* and *Myrsine coriaceae*. The species *Elionurus muticus*.

Aristida flaccida, *Axonopus suffultus*, *Andropogon lateralis*, *Eryngium ciliatum* and *Pinus* spec. showed the higher values of relative cover (RC; in that order of decreasing importance), and together accounted for 42% of the total RC. Table 2 shows the ten most representative species found in the sampling.

Table 1. Floristic table compiled from data recorded in grassland relict in the Botanical Garden, Porto Alegre, RS, Brazil. In the column “Survey”, P indicates that the species was found inside a plot of the quantitative sampling and F that it was found in the floristic sampling only (outside the plots).

Family	Species name	Author	Survey
Asteraceae	*Achyrocline mathiolaefolia*	DC.	P
Pteridaceae	*Adiantopsis chlorophylla*	(Sw.) Fée	F
Fabaceae	*Aeschynomene spec.*	L.	P
Asparagaceae	*Agave* spec.	L.	P
Sapindaceae	*Allophylus edulis*	(A. St.-Hil., A. Juss. & Cambess.) Hieron. *ex* Niederl.	P
Poaceae	*Andropogon lateralis*	Nees	P
Anemiaceae	*Anemia phyllitidis*	(L.) Sw.	P
Plantaginaceae	*Angelonia integerrima*	Spreng.	P
Poaceae	*Aristida filifolia*	(Arechav.) Herter	P
Poaceae	*Aristida flaccida*	Trin. & Rupr.	P
Poaceae	*Aristida jubata*	(Arechav.) Herter	P
Poaceae	*Aristida laevis*	(Nees) Kunth	P
Poaceae	*Aristida venustula*	Arechav.	F
Asteraceae	*Aspilia montevidensis*	(Spreng.) Kuntze	F
Fabaceae	*Ateleia glazioveana*	Baill.	P
Poaceae	*Axonopus argentinus*	Parodi	P
Poaceae	*Axonopus siccus*	(Nees) Kuhlm.	P
Poaceae	*Axonopus suffultus*	(Mikan ex Trin.) Parodi	P
Asteraceae	*Baccharis articulata*	(Lam.) Pers.	P
Asteraceae	*Baccharis caprariifolia*	DC.	P
Asteraceae	*Baccharis ochracea*	Spreng.	F
Asteraceae	*Baccharis patens*	Baker	P
Asteraceae	*Baccharis tridentata*	Vahl	P
Asteraceae	*Baccharis trimera*	(Less.) DC.	P
Rubiaceae	*Borreria capitata*	(Ruiz & Pav.) DC.	F
Rubiaceae	*Borreria dasycephala*	(Cham. & Schltdl.) Bacigalupo & E.L. Cabral	P
Rubiaceae	*Borreria eryngioides*	Cham. & Schltdl.	P
Poaceae	*Bothriochloa exaristata*	(Nash) Henrard	P
Cyperaceae	*Bulbostylis capillaris*	(L.) Kunth *ex* C.B. Clarke	P
Cyperaceae	*Bulbostylis juncoides*	(Vahl) Kük. *ex* Osten	P
Cyperaceae	*Bulbostylis sphaerocephala*	(Boeck.) C.B. Clarke	P
Cyperaceae	*Bulbostylis subtilis*	M.G. López	F
Arecaceae	*Butia odorata*	(Barb.Rodr.) Noblick & Lorenzi	F
Poaceae	*Calamagrostis viridiflavescens*	(Poir.) Steud.	F
Asteraceae	*Calea cymosa*	Less.	F
Asteraceae	*Calea pinnatifida*	(R.Br.) Banks ex Steud.	P
Asteraceae	*Calea uniflora*	Less.	P
Solanaceae	*Calibrachoa ovalifolia*	(Miers) Stehmann & Semir	F
Myrtaceae	*Campomanesia aurea*	O. Berg	P

Continue

Table 1. Continuation

Family	Species name	Author	Survey
Cyperaceae	*Carex phalaroides*	Kunth	F
Apiaceae	*Centella asiatica*	(L.) Urb.	P
Asteraceae	*Chaptalia runcinata*	Kunth	P
Asteraceae	*Chaptalia sinuata*	(Less.) Vent. *ex* Steud.	P
Poaceae	*Chascolytrum lamarckianum*	(Nees) Matthei	P
Poaceae	*Chascolytrum rufum*	(J. Presl) Steud.	F
Poaceae	*Chascolytrum scabrum*	(Nees *ex* Steud.) Matthei	P
Poaceae	*Chascolytrum subaristatum*	(Lam.) Desv.	P
Rubiaceae	*Chiococca alba*	(L.) Hitchc.	P
Rubiaceae	*Chomelia obtusa*	Cham. & Schltdl.	P
Asteraceae	*Chromolaena ascendens*	(Sch.Bip. ex Baker) R.M.King & H.Rob.	P
Asteraceae	*Chrysolaena flexuosa*	(Sims) H.Rob.	P
Vitaceae	*Cissus striata*	Ruiz & Pav.	P
Linaceae	*Cliococca selaginoides*	(Lam.) C.M. Rogers & Mildner	P
Fabaceae	*Clitoria nana*	Benth.	P
Commelinaceae	*Commelina diffusa*	Burm. f.	F
Asteraceae	*Conyza bonariensis*	(L.) Chronquist	P
Boraginaceae	*Cordia monosperma*	(Jacq.) Roem. & Schult.	P
Fabaceae	*Crotalaria tweediana*	Benth.	P
Euphorbiaceae	*Croton gnaphalii*	Baill.	P
Lythraceae	*Cuphea campylocentra*	Griseb.	P
Lythraceae	*Cuphea glutinosa*	Cham. & Schltdl.	P
Poaceae	*Danthonia cirrata*	Hack. & Arechav.	P
Fabaceae	*Desmanthus* sp.	Willd.	P
Fabaceae	*Desmodium incanum*	DC.	P
Poaceae	*Dichanthelium sabulorum*	(Lam.) Gould & C.A. Clark	P
Convolvulaceae	*Dichondra sericea*	Sw.	P
Asteraceae	*Disynaphia ligulifolia*	(Hook. & Arn.) R.M. King & H. Rob.	P
Asteraceae	*Disynaphia spathulata*	(Hook. & Arn.) R.M.King & H.Rob.	P
Sapindaceae	*Dodonaea viscosa*	Jacq.	P
Bromeliaceae	*Dyckia choristaminea*	Mez	P
Cyperaceae	*Eleocharis viridans*	Kük. ex Osten	F
Poaceae	*Elionurus muticus*	(Spreng.) Kuntze	P
Orchidaceae	*Epidendrum fulgens*	Brongn.	P
Poaceae	*Eragrostis neesii*	Trin.	F
Poaceae	*Eragrostis polytricha*	Nees	P
Apiaceae	*Eryngium ciliatum*	Cham. & Schltdl.	P
Apiaceae	*Eryngium elegans*	Cham. & Schltdl.	P
Apiaceae	*Eryngium horridum*	Malme	P
Apiaceae	*Eryngium sanguisorba*	Cham. & Schltdl.	F

Continue

Table 1. Continuation

Family	Species name	Author	Survey
Erythroxylaceae	*Erythroxylum argentinum*	O.E. Schulz	P
Euphorbiaceae	*Euphorbia selloi*	(Klotzsch & Garcke) Boiss.	P
Convolvulaceae	*Evolvulus sericeus*	Sw.	P
Fabaceae	*Galactia gracillima*	Benth.	P
Fabaceae	*Galactia marginalis*	Benth.	P
Fabaceae	*Galactia pretiosa*	Burkart	P
Rubiaceae	*Galianthe fastigiata*	Griseb.	P
Rubiaceae	*Galium hirtum*	Lam.	P
Rubiaceae	*Galium hypocarpium*	(L.) Endl. *ex* Griseb.	P
Rubiaceae	*Galium richardianum*	(Gillies *ex* Hook. & Arn.) Endl. ex Walp.	P
Asteraceae	*Gamochaeta americana*	(Mill.) Weddell	P
Verbenaceae	*Glandularia marrubioides*	(Cham.) Tronc.	F
Verbenaceae	*Glandularia peruviana*	(L.) Small	P
Lamiaceae	*Glechon ciliata*	Benth.	P
Asteraceae	*Grazielia serrata*	(Spreng.) R.M.King & H.Rob.	P
Proteaceae	*Grevillea robusta*	A. Cunn. *ex* R. Br.	P
Asteraceae	*Gyptis pinnatifida*	Cass.	P
Asteraceae	*Hatschbachiella tweedieana*	(Hook. *ex* Hook. & Arn.) R.M.King & H.Rob.	F
Iridaceae	*Herbertia lahue*	(Molina) Goldblatt	F
Iridaceae	*Herbertia pulchella*	Sweet	F
Asteraceae	*Heterothalamus psiadioides*	Less.	P
Asteraceae	*Hieracium commersonii*	Monnier	F
Poaceae	*Homolepis glutinosa*	(Sw.) Zuloaga & Soderstr.	F
Araliaceae	*Hydrocotyle exigua*	Malme	P
Hypericaceae	*Hypericum caprifoliatum*	Cham. & Schltdl.	P
Asteraceae	*Hypochaeris tropicalis*	Cabrera	P
Hypoxidaceae	*Hypoxis decumbens*	L.	P
Convolvulaceae	*Ipomoea cairica*	(L.) Sweet	P
Iridaceae	*Iris* spec.	L.	F
Asteraceae	*Isostigma peucedanifolium*	(Spreng.) Less.	F
Malpighiaceae	*Janusia guaranitica*	(A. St.-Hil.) A. Juss.	P
Juncaceae	*Juncus* spec.	L.	P
Verbenaceae	*Lantana camara*	L.	P
Verbenaceae	*Lantana montevidensis*	(Spreng.) Briq.	P
Melastomataceae	*Leandra australis*	(Cham.) Cogn.	P
Poaceae	*Leptocoryphium lanatum*	(Kunth) Nees	P
Asteraceae	*Lessingianthus brevifolius*	(Less.) H.Rob.	P
Asteraceae	*Lessingianthus rubricaulis*	H.Rob.	P
Asteraceae	*Lessingianthus sellowii*	(Less.) H.Rob.	P
Asteraceae	*Lucilia acutifolia*	(Poir.) Cass.	P
Asteraceae	*Lucilia nitens*	Less.	P

Continue

Table 1. Continuation

Family	Species name	Author	Survey
Apocynaceae	*Macrosiphonia longiflora*	(Desf.) Müll. Arg.	P
Plantaginaceae	*Mecardonia procumbens*	(Mill.) Small	P
Fabaceae	*Mimosa bimucronata*	(DC.) Kuntze	F
Myrtaceae	*Myrcia palustris*	DC.	P
Myrtaceae	*Myrcia selloi*	(Spreng.) N. Silveira	P
Primulaceae	*Myrsine coriacea*	(Sw.) R. Br. *ex* Roem. & Schult.	P
Primulaceae	*Myrsine guianensis*	(Aubl.) Kuntze	P
Asteraceae	*Orthopappus angustifolius*	(Sw.) Gleason	P
Oxalidaceae	*Oxalis brasiliensis*	G. Lodd.	P
Oxalidaceae	*Oxalis conorrhiza*	Jacq.	P
Oxalidaceae	*Oxalis* spec.	L.	P
Poaceae	*Panicum peladoense*	Henrard	P
Poaceae	*Paspalum plicatulum*	Michx.	P
Poaceae	*Paspalum umbrosum*	Trin.	F
Passifloraceae	*Passiflora alata*	Curtis	F
Passifloraceae	*Passiflora misera*	Kunth	P
Passifloraceae	*Passiflora suberosa*	L.	P
Lamiaceae	*Peltodon longipes*	A. St.-Hil. *ex* Benth.	P
Amaranthaceae	*Pfaffia tuberosa*	Hicken	P
Pinaceae	*Pinus* spec.	L.	P
Poaceae	*Piptochaetium montevidense*	(Spreng.) Parodi	P
Plantaginaceae	*Plantago brasiliensis*	Sims	P
Polygalaceae	*Polygala linoides*	Poir.	F
Polygalaceae	*Polygala molluginifolia*	A. St.-Hil. & Moq.	F
Asteraceae	*Porophyllum lanceolatum*	DC.	P
Orchidaceae	*Prescottia densiflora*	(Brongn.) Lindl.	P
Rosaceae	*Prunus myrtifolia*	(L.) Urb.	P
Myrtaceae	*Psidium salutare var. mucronatum*	(Cambess.) Landrum	P
Rubiaceae	*Psychotria nuda*	(Cham. & Schltdl.) Wawra	F
Asteraceae	*Pterocaulon angustifolium*	DC.	P
Asteraceae	*Pterocaulon rugosum*	(Vahl) Malme	P
Cyperaceae	*Rhynchospora barrosiana*	Guagl.	P
Cyperaceae	*Rhynchospora setigera*	(Kunth) Boeck.	P
Rubiaceae	*Richardia brasiliensis*	Gomes	F
Rubiaceae	*Richardia grandiflora*	(Cham. & Schltdl.) Steud.	P
Rubiaceae	*Richardia humistrata*	(Cham. & Schltdl.) Steud.	F
Poaceae	*Saccharum angustifolium*	(Nees) Trin.	F
Anacardiaceae	*Schinus terebinthifolius*	Raddi	P
Poaceae	*Schizachyrium microstachyum*	(Desv. *ex* Ham.) Roseng., B.R. Arrill. & Izag.	P
Poaceae	*Schizachyrium tenerum*	Nees	P
Asteraceae	*Schlechtendalia luzulifolia*	Less.	P

Continue

Table 1. Continuation

Family	Species name	Author	Survey
Cyperaceae	*Scleria sellowiana*	Kunth	P
Asteraceae	*Senecio leptolobus*	DC.	F
Poaceae	*Setaria parviflora*	(Poir.) Kerguélen	F
Poaceae	*Setaria vaginata*	Spreng	F
Iridaceae	*Sisyrinchium micranthum*	Cav.	P
Iridaceae	*Sisyrinchium palmifolium*	L.	P
Smilacaceae	*Smilax campestris*	Griseb.	P
Smilacaceae	*Smilax cognata*	Kunth	P
Solanaceae	*Solanum mauritianum*	Scop.	F
Solanaceae	*Solanum pseudocapsicum*	L.	P
Solanaceae	*Solanum pseudoquina*	A. St.-Hil.	P
Asteraceae	*Sonchus oleraceus*	(L.) L.	F
Rubiaceae	*Spermacoce verticillata*	L.	P
Poaceae	*Sporobolus multinodis*	Hack.	P
Verbenaceae	*Stachytarpheta cayennensis*	(Rich.) Vahl	F
Asteraceae	*Stenachaenium riedelii*	Baker	F
Asteraceae	*Stenocephalum megapotamicum*	(Spreng.) Sch.Bip.	P
Poaceae	*Stenotaphrum secundatum*	(Walter) Kuntze	F
Fabaceae	*Stylosanthes montevidensis*	Vogel	P
Myrtaceae	*Syzygium cumini*	(L.) Skeels	P
Melastomataceae	*Tibouchina gracilis*	(Bonpl.) Cogn.	P
Poaceae	*Trachypogon spicatus*	(L. f.) Kuntze	P
Cannabaceae	*Trema micrantha*	(L.) Blume	F
Passifloraceae	*Turnera sidoides*	L.	P
Asteraceae	*Vernonanthura nudiflora*	(Less.) H.Rob.	P
Campanulaceae	*Wahlenbergia linarioides*	(Lam.) A. DC.	F
Malvaceae	*Waltheria douradinha*	A. St.-Hil.	F
Xyridaceae	*Xyris* spec.	L.	F
Fabaceae	*Zornia* spec.	J.F. Gmel.	P

Table 2. Species with the greatest importance values found in a survey of relict grassland inside the Botanical Garden, Porto Alegre, RS, Brazil. Given are Relative Frequency (RF), Relative Cover (RC) and Importance Value (IV).

Family	Biological form	Species	RF (%)	RC (%)	IV (%)
Poaceae	Grass	*Elionurus muticus*	2.10	6.06	4.08
Poaceae	Grass	*Aristida flaccida*	2.68	2.89	2.78
Poaceae	Grass	*Axonopus suffultus*	1.98	3.55	2.77
Poaceae	Grass	*Sporobolus multinodis*	0.35	4.99	2.67
Poaceae	Grass	*Schizachyrium tenerum*	0.58	4.08	2.33
Poaceae	Grass	*Aristida filifolia*	0.35	4.22	2.29
Apiaceae	Forb	*Eryngium ciliatum*	2.56	1.08	1.82
Pinaceae	Tree	*Pinus* spec.	2.56	1.00	1.78
Poaceae	Grass	*Andropogon lateralis*	1.63	1.80	1.71
Poaceae	Grass	*Aristida laevis*	1.05	2.34	1.69

The plant family *Asteraceae* was the most species rich (34 species), followed by *Poaceae* (25 spp), *Fabaceae* (12 spp) and *Rubiaceae* (11 spp). Interestingly, among the herbaceous species, *Schlechtendalia luzulifolia*, an endangered plant (Rio Grande do Sul 2003), was within the ten with the highest coverage. Other endangered species were also found in the area: *Butia odorata*, *Dyckia choristaminea*, *Eugenia dimorpha* and *Waltheria douradinha*. We found ten species considered endemic to the Pampa biome (Boldrini *et al*., in prep.): *Baccharis patens*, *Calibrachoa ovalifolia*, *Clitoria nana*, *Crotalaria tweediana*, *Dyckia choristaminea*, *Eugenia dimorpha*, *Herbertia pulchella*, *Galium hirtum*, *Piriqueta suborbicularis* and *Turnera sidoides*. It is worth highlighting the presence of some relatively rare species such as *Lippia pusilla*, *Isostigma peucedanifolium* and *Mandevilla longiflora*. The endangered *Bromeliaceae Dyckia leptostachya* had been registered for the area (Bueno & Martins 1986), but was not found again in this study. Six exotic species were found in the grassland fragment: *Agave* spec., *Grevillea robusta*, *Iris* spec., *Pinus* spec., *Sonchus oleraceus* and *Syzygium cumini*; besides, *Ateleia glazioviana,* a native species in Rio Grande do Sul, but not naturally occurring in the hills of Porto Alegre. The invasive tree *Pinus* spec. was highly frequent: it was found in 73% of the all plots, with a mean value of 4.6 individuals (seedlings) / m².

Most species occurred with low frequency values, *i. e.*, 54% of the species found in our samples (80 spp.) were not present in more than three plots. This apparent pattern of high species turnover between plots also becomes clear when we considering the number of shared species: a mean number of 9 species (ranging between 1 and 20) was shared between sampling units when comparing all possible combinations of plots.

The woody vegetation on the edge of the fragment is characterized by the presence of *Ateleia glazioviana*, *Casearia sylvestris*, *Lithraea brasiliensis* and *Myrcia palustris* and other species typical of forest edges. Some lianas were also found inside the grassland fragment (*e. g.*, *Cissus striata*, *Janusia guaranitica*, *Smilax campestris*, *Passiflora suberosa*, *P. misera*).

Among the 39 species shared between our and other studies of grasslands in the granitic hills of Porto Alegre (complete list not shown) are grasses with high cover value such as *Andropogon lateralis*, *Aristida flaccida*, *Elionurus muticus* and *Trachypogon montufarii*, which suggests similar patterns of vegetation structure. The comparison of areas by help of the Jaccard index shows that the differences of the grassland relict in the Botanical Garden to the other grasslands were rather similar to those between the latter (Table 3).

Table 3. Jaccard index values among grassland communities in the granitic hills of Porto Alegre: Botanical Garden (this study), Santana hill (Overbeck et al. 2006), Osso hill (Ferreira et al. 2010) and Police hill (Boldrini et al. 1998). Only species fully identified were used for this analysis.

	Botanical Garden	Santana hill	Osso hill	Police hill
Botanical Garden	1			
Santana hill	0.329	1		
Osso hill	0.228	0.359	1	
Polícia hill	0.228	0.291	0.347	1
Species found	183	165	152	171
Sampling method/plot size	30 plots 1 m²	48 plots 0,75 m²	39 plots 1 m²	2829 points

DISCUSSION

Contrary to our initial hypothesis that reduced species richness would be found as a consequence of absence of management by grazing or fire, our data shows that the grassland relict holds a high number of species. The structural patterns are quite characteristic for grasslands in the hills in Porto Alegre (*e. g.* Overbeck *et al*., 2005, 2006; Setubal & Boldrini, 2012). The species composition as well as the soil characteristics indicate that the grassland relict can be considered rocky grassland (*campo rupestre*), a grassland formation typical of the tops or steeper slope of the hills, with shallow soil and often rock outcrops. Setubal & Boldrini (2012) consider the grasses *Axonopus siccus*, *A. suffultus* and *Trachypogon montufari* as species indicative of this type of community– these species all had high cover values in our study as well. Even though the studied grassland patch is suffering from invasion by shrubs and trees and has been substantially reduced concerning its total area (from 0.3 ha in 1985 to 0.15 in 2011), the high species richness of the small area is surprising. Among the species present we found five that are included in the list of endangered flora of Rio Grande do Sul state (Rio Grande do Sul 2003), which along with the total species richness underscores the importance of this relict for conservation of the biodiversity of the granitic hills of Porto Alegre. Most likely, a longer study period would yield an even higher species number.

The available literature concerning vegetation dynamics in South Brazilian grasslands indicate that disturbances (fire or grazing) are necessary to impede competitive dominance of tussock grasses, losses of plant diversity and, ultimately, transformation to shrub and tree dominated vegetation (Müller *et al.*, 2007; Overbeck *et al.*, 2005, 2007; Pillar & Vélez, 2010). However, the situation seems to be different in our study area. Even though in some plots we found high levels of dominance by few species, most of them were quite heterogeneous, and no overall decline of species richness due to lack of management could be observed – indicated by the high species number per plot. Apparently, the specific site conditions of the rocky grassland with its shallow soils (and associated with it, low water availability) limit growth and biomass accumulation of the tussock grasses, thus preventing their dominance and subsequent loss of interstitial species (Overbeck *et al.*, 2005). Invasion of shrub and tree species as well of lianas is evident in the study area, but the management – periodic removal of these species – apparently is sufficient to impede transformation of the area into shrubland or forest, while no reduction of richness seems to occur in the herbaceous layer.

It has been shown for the granitic hills of Porto Alegre that, in the absence of disturbance (fire or grazing), succession processes to forest can be quite fast, as a consequence of shrub encroachment and the nucleating effect of pioneer tree species (Müller *et al*., 2007, 2012). In our study, the presence of woody species and of lianas is evidence of such processes, which can be expected to be quite fast for the studied area, given its small total size, if removal of woody species was stopped. The highest risk for plant diversity and vegetation structure of the area, however, comes from the constant invasion of the exotic invasive tree *Pinus* spec., a pioneer species that easily colonizes grassland areas in Southern Brazil. In the case of the grassland fragment in the Botanical Garden area, constant seed rain from individuals planted on the other side of the wall that surrounds the area makes removal of seedlings a constant task.

Will continuing the current management guarantee the maintenance of the grassland relict and its plant diversity? Shouldn't fire or grazing be considered as likely more adequate forms of management? Given the small size of the area and its location within the Botanical Garden, in the urban matrix, the disturbance regime common in other grasslands in the hills of Porto Alegre, fire, does not seem an appropriate management tool in this case, even though our knowledge on its effects permits the conclusion that it would not have negative effects on the plant community (Overbeck *et al.*, 2005) and would be efficient in impede succession to forest (Müller *et al*., 2007). However some species might be favored by this kind of disturbance (*e. g*. from the genus *Eryngium*; Fidelis *et al*., 2008). In principle, grazing would be an alternative options, but again, the small size of the fragment as well as logistic questions (no presence of grazing animals nearby) rule this kind of management out for the area, besides the fact that this most likely would invoke changes in community structure and composition (*e. g.* increase of creeping, rhizomatous and stoloniferous grass especies, such as *Paspalum notatum*, *Paspalum plicatulum* or *Axonopus affinis*, which are typical for grazed grasslands; Boldrini & Eggers, 1996). Apparently, removal of shrub and trees, but not of herbaceous biomass, has been sufficient for preservation of the characteristic species set of rocky grassland at this site, even though losses in size of the fragment could not be avoided. However, periodic mowing (every one or two years) might be an interesting management option that would also reduce the woody species component. At any rate, both the continuation of the present management, as well as the introduction of any other options, should be accompanied by scientific monitoring of management effects. Considering the encroachment of forest vegetation over the grassland relict in the past years, a stepwise reduction of the forest belt additionally seems to be an interesting option.

The insertion of a culture favorable to biodiversity conservation in a society begins with the establishment and management of protected areas open to the public, where the population has the possibility get to know and experience natural environments and understand their importance for their own well-being. This is even more important in large cities where most of the population has no or little access to natural ecosystems. The grassland relict we studied is situated within Porto Alegre's Botanical Garden, an institution dedicated to conservation, research and environmental education. The high species richness and its high number of endangered species call for a prominent place of the area on the list of conservation activities of the Botanical Garden, especially as the area is a remnant of natural vegetation within a larger area subjected to gardening activities, *i.e*., in principle, vegetation of this fragment is irreplaceable on its site. In addition to this, as it is an area of natural grassland with easy accessibility, a high potential exists for use of this grassland fragment to raise awareness for conservation of grassland ecosystems among the visitors of the Botanical Garden, for example by help of a presentation of its principal characteristics and adequate educational activities to the public. A formal management plan for the area and consideration in educative activities thus seem to be of high importance – together with the removal of the neighboring *Pinus* trees. Conservation of this area might also be an impulse to initiate more visible approaches of biodiversity conservation within the urban context.

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REFERENCES

Adelmann, W., G. E. Overbeck, A. Zellhuber, S. C. Müller, E. D. Forneck, M. Drösler, J. Pfadenhauer, V. D. Pillar & M. L. Porto. 2011. Supporting the Ecosystem Approach within urban development planning of Porto Alegre, Brazil. *In* Das Übereinkommen über die Biologische Vielfalt (CBD) - ein Einstieg für Wissenschaftler (A. Paulsch & C. Paulsch, eds.). Regensburg: IBN - Institut für Biodiversität Netzwerk, e.V., p. 113-133.

Amaral, D. D., I. C. Vieira, R. P. Salomão, S. S. Almeida & M. A. Jardim. 2012. The status of conservation of urban forests in eastern Amazonia. Brazilian Journal of Biology, 72: 257-265.

APG III. Angiosperms Phylogeny Group III Classification. 2009. An update of Angiosperm Phylogeny Group Classification for the orders and families of flowering plants: APG III. Botanical Journal of the Linnean Society, 161: 105-121.

Behling, H., V. D. Pillar, S. C. Müller, G. E. Overbeck. 2007. Late-Holocene fire history in a forest-grassland mosaic in southern Brasil: Implications for conservation. Applied Vegetation Science, 10: 81-90.

Boldrini, I. I., S. T. S. Miotto, H. M. Longhi-Wagner, V. D. Pillar & K. Marzall. 1998. Aspectos florísticos e ecológicos da vegetação campestre do Morro da Polícia, Porto Alegre, RS, Brasil. Acta Botanica Brasilica, 12: 89-100.

Boldrini, I.I & L. Eggers. 1996. Vegetação campestre do Sul do Brasil: Dinâmica de espécies à exclusão do gado. Acta Botânica Brasilica, 10: 37-50

Boldrini, I. I., R. Setubal, A. A. Scheider & R. Trevisan (in preparation): Checklist of angiosperm grassland flora of Rio Grande do Sul, Brazil.

Bueno, O. L. & S. M. A. Martins. 1986. A flora e vegetação espontânea do Jardim Botânico de Porto Alegre, RS, Brasil. Fanerógamas herbáceas e arbustivas. Iheringia, Série Botânica, 35: 2-23.

Chamberlain, D. E., A. R. Cannon & M. P. Toms. 2004. Associations of garden birds with gradients in garden habitat and local habitat. Ecography, 27: 589-600.

Chao, A. 1987. Estimating the population size for capture-recapture data with unequal catchability. Biometrics, 43: 783-791.

Colwell, R. K. 2009. EstimateS: Statistical estimation of species richness and shared species from samples. Version 8.2. User's Guide and application published at: http://purl.oclc.org/estimates.

Colwell, R. K. & J. A. Coddington. 1994. Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society (Series B), 345: 101-118.

Dobbs, C., F. J. Escobedo & W. C. Zipperer. 2011. A framework for developing urban forest ecosystem services and goods indicators. Landscape and Urban Planning, 99: 196-206.

Ferreira, P. M. D. A., S. C. Müller, I. I. O. B. Boldrini & L. Eggers. 2010. Floristic and vegetation structure of a granitic grassland in Southern Brazil. Revista Brasileira de Botânica, 33: 21-36.

Fidelis, A., G. E. Overbeck, V. D. Pillar & J. Pfadenhauer. 2008. Effects of disturbance on population biology of the rosette species *Eryngium horridum* Malme in grasslands in southern Brazil. Plant Ecology, 195: 55-67.

Lerman, S. B. & P. S. Warren. 2011. The conservation value of residential yards: linking birds and people. Ecological applications, 21: 1327-1339.

Lienert, J. 2004. Habitat fragmentation effects on fitness of plant populations – a review. Journal for Nature Conservation, 12: 53-72.

Lopes, S. B. (Ed.). 2004. Plano Diretor do Jardim Botânico de Porto Alegre. Fundação Zoobotânica do Rio Grande do Sul, Porto Alegre.

Menegat, R. (Ed.). 2006. Atlas ambiental de Porto Alegre, 3rd edition. Editora da UFRGS, Porto Alegre.

Müller-Dombois, D. & H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley, New York.

Müller, S. C., G. E. Overbeck, J. Pfadenhauer & V. D. Pillar. 2007. Plant Functional Types of Woody Species Related to Fire Disturbance in Forest–Grassland Ecotones. Plant Ecology, 189: 1-14.

Müller, S. C., G. E. Overbeck, J. Pfadenhauer & V. D. Pillar. 2012. Woody species patterns at forest-grassland boundaries in southern Brazil. Flora, 207: 586-598.

Niemelã, J., J. H. Breuste, G. Guntenspergen, N. E. McIntyre, T. Elmqvist & P. James (Eds.). 2011. Urban Ecology Patterns, Processes, and Applications. Oxford University Press.

Overbeck, G. E., S. C. Müller, V. D. Pillar & J. Pfadenhauer. 2005. Fine-scale post-fire dynamics in southern Brazilian subtropical grassland. Journal of Vegetation Science, 16: 655-664.

Overbeck, G. E., S. C. Müller, V. D. Pillar & J. Pfadenhauer. 2006. Floristic composition, environmental variation and species distribution patterns in burned grassland in southern Brazil. Brazilian Journal of Biology, 66: 1073-1090.

Overbeck, G. E., S. Müller, A. Fidelis, J. Pfadenhauer, V. Pillar, C. Blanco, I. Boldrini, R. Both, and E. Forneck. 2007. Brazil's neglected biome: The South Brazilian Campos. Perspectives in Plant Ecology, Evolution and Systematics, 9: 101-116.

Overbeck, G. E., S. C. Müller, V. D. Pillar & R. B. Setubal. 2011. Propostas de manejo e conservação para os campos. *In* Campos dos morros de Porto Alegre (R. B. Setubal, I. I. Boldrini, P. M. A., eds.). Porto Alegre: Igré Associação Sócio-Ambientalista, p. 95-98.

Pillar, V. D. P. & E. Vélez. 2010. Extinção dos Campos Sulinos em Unidades de Conservação: um Fenômeno Natural ou um Problema ético? Natureza & Conservação, 8: p. 84–86.

Pysek, P. 1993. Factors affecting the diversity of flora and vegetation in central European settlements. Vegetation, 106: p. 89-100.

Rio Grande do Sul. 2003. Decreto estadual n 42.099, publicado no Diário Oficial do estado do Rio Grande do Sul, n 1, em 1/01/2003.

Santos, H. G., P. K. T. Jacomine, L. H. C. Anjos, V. A. Oliveira, J. B. Oliveira, M. R. Coelho, J. F. Lumbreras & T. J. F. Cunha (Eds.). 2006. Sistema brasileiro de classificação de solos, 2 ed. Embrapa Solos, Rio de Janeiro.

Setubal, R.B., Boldrini, I.I. & Ferreira, P.M.A. (Org.). 2011. Campos dos morros de Porto Alegre. Porto Alegre: Igré Associação Sócio-Ambientalista.

Setubal, R. B. & I. I. Boldrini. 2012. Phytosociology and natural subtropical grassland communities in a granitic hill in southern Brazil. Rodriguésia, 63: 513-524.

Smith, E. P. & G. B. Belle. 1984. Nonparametric estimation of species richness. Biometrics, 40: 119-129.

Sushinsky, J. R., J. R. Rhodes, H. P. Possingham, T. K. Gill & R. A. Fuller. 2013. How should we grow cities to minimize their biodiversity impacts? Global Change Biology, 19: 401-410.

Tropicos.org. Missouri Botanical Garden. 10 May 2013 <http://www.tropicos.org>

Zerbe, S., U. Maurer, S. Schmitz & H. Sukopp, H. 2003: Biodiversity in Berlin and its potential for nature conservation. Landscape and Urban Planning, 62: 139-148.