

UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
INSTITUTO DE BIOCIÊNCIAS
PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA

Dissertação de Mestrado

REDUNDÂNCIA FUNCIONAL EM COMUNIDADES CAMPESTRES

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Porto Alegre (RS), Brasil
Fevereiro de 2008

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Dissertação apresentada ao Programa de Pós-graduação em Ecologia, do Instituto de Biociências da Universidade Federal do Rio Grande do Sul, como parte dos requisitos para obtenção do título de Mestre em Ecologia.

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Porto Alegre, fevereiro de 2008

“Ali, nos mirantes mais altos do Rio Grande do Sul, com as forças milenares da erosão a trabalhar diante dos olhos, com os temerosos abismos dos canhões aos pés, com o pinhal, a mata branca e o campo, tão rio-grandenses, em derredor, com o oceano no horizonte, as gerações futuras nos hão de agradecer a piedade e reverência com que conservamos as mais grandiosas paisagens da nossa terra.”

Pe. Balduíno Rambo – A fisionomia do Rio Grande do Sul

AGRADECIMENTOS

Todas as vezes que, ao final do dia, antes de fechar a porta, contemplava o laboratório me recordava das dificuldades e do esforço que fiz para chegar ali, praticando a arte de desfrutar daquilo que já conquistei. Alegrava-me com a lembrança do convívio com todos os habitantes daquele n-dimensional mundo Ecoqua, aos quais dedico meus agradecimentos em especial:

Ao meu orientador Valério De Patta Pillar, por me instigar a aceitar todos os desafios, principalmente à abordagem experimental e pela confiança depositada.

À minha coorientadora Sandra Cristina Müller por me mostrar e advertir das limitações que eu encontraria no percurso da prática do meu trabalho.

Aos colegas do Laboratório de Ecologia Quantitativa Melina, Juliano, Alessandra, Carolina, Marcos, Gabriel, Max, Marcel, Letícia, Adriana, Rita, Eduardo, Camila e Betânia.

À Professora Ilsi Boldrini e à Alessandra Fidelis, Ângelo Schneider e Rafael Trevisan pela grande contribuição na identificação das espécies coletadas.

Aos muito especiais colegas de mestrado, João, André, Letícia, Claudia, Raul e Melina.

Ao José Pedro Trindade pela presteza, amizade e contribuição com as fotos.

Ao André T. Lanzer pela amizade e dedicação

Ao Programa de Pós-Graduação em Ecologia e aos professores.

À CAPES pela concessão de bolsa de mestrado

À EMBRAPA pelo financiamento do projeto

À Estação Experimental Agronômica da UFRGS

Dedico este trabalho aos meus pais e irmãos, por tudo e à minha noiva Gabriele pela ajuda, paciência, dedicação e carinho.

REDUNDÂNCIA FUNCIONAL EM COMUNIDADES CAMPESTRES

RESUMO

Os campos do Rio Grande do Sul apresentam grande biodiversidade, beleza cênica e um importante recurso para a economia do estado, cuja principal atividade é a pecuária. O manejo inadequado do campo traz consequências graves para a diversidade e sustentabilidade desse ecossistema através da perda de espécies promovida pelo pastejo excessivo. Entretanto, algumas espécies desempenham as mesmas funções nos ecossistemas, logo a perda de algumas espécies pode não afetar o seu funcionamento, pela compensação de outras espécies do mesmo grupo funcional. Esta redundância funcional aumentaria a confiabilidade do funcionamento do ecossistema quando perturbado, funcionando como um tipo de “seguro” contra a perda de espécies. A hipótese da redundância funcional foi avaliada em ecossistemas campestres através de um experimento de remoção no qual os tratamentos avaliados consistiram em: 1) remoção de duas espécies graminóides, 2) remoção de duas espécies herbáceas não-graminóides, 3) remoção de uma espécie de graminóide e uma herbácea não-graminóide e 4) sem remoção. As evidências indicam que existe redundância funcional para as espécies de plantas em ecossistemas campestres, pois a remoção de uma espécie de cada grupo funcional causou menos modificações na composição de espécies das comunidades que a remoção de duas espécies do mesmo grupo funcional. Observou-se também que a porcentagem da cobertura das espécies remanescentes tende a compensar a remoção de espécies do mesmo grupo funcional. Entretanto, os tratamentos não tiveram efeito para a biomassa aérea. A avaliação de um banco de dados de um experimento de pastejo realizado anteriormente revelou que a redundância funcional está positivamente relacionada com a resistência da comunidade ao pastejo, enquanto a riqueza de espécies não apresentou relação. Áreas de campo com maiores níveis de redundância funcional são mais resistentes ao pastejo, sofrendo menos modificações na composição de espécies de suas comunidades. Além disso, um manejo adequado não reduz os níveis de redundância funcional dos campos. Áreas de campo dentro de unidades de conservação deveriam ser manejadas adequadamente mantendo os níveis de redundância funcional e a estabilidade deste ecossistema. Entretanto, novos estudos são necessários para avaliar a importância da redundância funcional em experimentos de longa duração.

Palavras-chave: Funcionamento do ecossistema, Campos, experimento de remoção, resistência, pastejo, grupos funcionais.

FUNCTIONAL REDUNDANCY IN GRASSLAND PLANT COMMUNITIES

ABSTRACT

Grasslands from Rio Grande do Sul present great biodiversity, scenic beauty and an important resource to the province economy, which main activity is cattle grazing. Inadequate pasture management brings serious consequences to ecosystem diversity and sustainability by the loss of species promoted by excessive grazing. Although, some species may role the same functions in ecosystems, therefore loss of some species may not affect functioning, due to species compensation within functional groups. This functional redundancy would increase ecosystem reliability when perturbations occur, working as an “insurance” to species loss. Functional redundancy hypothesis was evidenced in grassland plant communities through a removal experiment in which evaluated treatments were: 1) removal of two graminoid species, 2) removal of two forb species, 3) removal of one species of each functional group and 4) no removal (control). Evidences point to functional redundancy for grassland plant species; removal of one species of each functional group caused less harm to community species composition than removal of two species of the same functional group. Furthermore, remaining species percent covers tend to compensate removed species of the same functional group. However, treatments did not effected aboveground biomass. Data set evaluation of a previously conducted cattle-grazing experiment reveled that functional redundancy is positively related to community resistance to cattle grazing, otherwise species richness presented no relation. Grassland areas with higher levels of functional redundancy are more resistant to cattle grazing, suffering less modification in community species composition. Also, adequate management do not reduce functional redundancy on pastures. Grassland areas inside conservation units should be managed adequately maintaining redundancy levels and ecosystem reliability. Although, new studies are required to better evaluate functional redundancy implications in long term experiments.

Key words: Ecosystem functioning, grasslands, removal experiment, resistance, grazing, functional groups.

SUMÁRIO

	Página
Introdução.....	09
Os campos do Rio Grande do Sul.....	09
Estabilidade x complexidade e o conceito de redundância funcional.....	10
A abordagem de grupos funcionais.....	11
Experimentos de remoção e o estudo da vegetação.....	12
Sobre o desenvolvimento do trabalho.....	13
Capítulo 1 - Quando os prédios caem, as máquinas param e os ecossistemas perdem espécies: um pequeno ensaio sobre a teoria da redundância funcional.....	14
Referências bibliográficas.....	20
Capítulo 2 – Functional Redundancy in a Removal Experiment on Grassland Plant Communities.....	21
Summary.....	21
Introduction.....	22
Methods.....	24
Study site.....	24
Experimental design.....	24
Vegetation assessment and species removal	26
The removal response coefficient	26
Data analysis	27
Caution on removal experiment responses interpretation.....	28
Results.....	28
Effect of species removal on composition change and aboveground biomass	29
Species loss compensation and the removal response coefficient.....	31
Discussion.....	33
Acknowledgements.....	37
References.....	38
Capítulo 3 - The Role of Functional Redundancy to Grassland Plant Community Resistance to Grazing.....	41
Introduction	41
Methods.....	42
Results.....	44
Discussion.....	46
Acknowledgements.....	47
Cited references.....	48
Redundância funcional e suas limitações e implicações para a conservação dos campos e práticas de manejo	
- Considerações finais.....	50
Referências Bibliográficas.....	53
Apêndices.....	56

LISTA DE FIGURAS

CAPÍTULO 1:	Página
Figura 1. O colápsio do prédio residencial Ronan Point (Great Britain Department of the Environment, 1973).....	14
FIGURA 2 Área de campo completamente dominada por <i>Dicondra sericea</i> e a destituição completa de espécies graminoides (Foto: José Pedro Pereira Trindade).	17
FIGURA 3. Degradação e arenização facilitadas pelo pastejo excessivo dos campos da Campanha gaúcha próximo aos areais de Manuel Viana (Foto: José Pedro Pereira Trindade). ..	19
CAPÍTULO 2:	
FIGURA 1. Mean and standard errors (n= 36) of residuals of the analysis on the effect of clipped biomass in the species removal treatments on (a) aboveground biomass and (b) community composition change measured by chord distance. Treatments were: GG – removal of two graminoid species, FF – removal of two forb species, GF – removal of one graminoid and one forb species and Control – no removal.....	30
FIGURA 2. Mean and standard error over 36 replicates of the proportional increment of percent cover (increment / initial percent cover) of (a) remaining graminoid species and (b) remaining forb species in response to removal treatments; GG – removal of two graminoid species, FF – removal of two forb species, GF – removal of one graminoid and one forb species and Control – no removal.....	32
FIGURA 3. Competition between and within functional groups measured by removal response coefficient (mean and standard error over 36 replicates) in response to removal of two graminoid species (GG) and two forb species (FF) on graminoid standing species and on forb standing species..	33
CAPÍTULO 3:	
FIGURE 1. Relation of initial species richness to resistance on composition change (Sorensen index between final and initial states based on presence and absence of species) duo to cattle grazing.	45
FIGURE 2. Relation of functional redundancy (initial number of species per functional group) to resistance on composition change (Sorensen index between final and initial states based on presence and absence of species) duo to cattle grazing. Species grouped into four functional groups.....	46

INTRODUÇÃO

Os campos do Rio Grande do Sul

Desde cedo em sua história, o homem teve uma relação bastante íntima com a vegetação de fisionomias abertas, tais como pradarias, campos, savanas e estepes, inicialmente pela caça e depois pela pecuária para obtenção de recursos e sustento. Os campos já ocuparam quase 50% do estado do Rio Grande do Sul (Rambo 1956) apresentando uma riqueza singular em espécies de plantas herbáceas e constituindo junto com os campos do Uruguai e Argentina uma das regiões mais ricas do mundo em gramíneas (Boldrini 1993). “Campos do Rio Grande do Sul” é uma denominação geral para as formações campestres encontradas neste estado e incluem unidades de dois domínios fitogeográficos diferentes. Os ditos campos de cima da serra, encontrados na metade norte do estado, estão ligados ao bioma Mata Atlântica e assim ao domínio fitogeográfico Amazônico (província Paranaense). Estes são geralmente permeados por capões de Floresta Ombrófila Mista. Os campos da campanha gaúcha, na metade sul do estado, abaixo da latitude 30°, fazem parte do bioma Pampa e pertencem ao domínio fitogeográfico Chaquenho (província Pampeana), estendendo-se ao Uruguai e Argentina (Cabrera e Willink 1980).

Embora as formações florestais sejam hoje bastante freqüentes, principalmente na metade norte, a vegetação campestre é mais antiga (Rambo 1956, Behling 1998, 2002, Ledru et al. 1998, Behling et al. 2007). O clima hoje é ideal para as formações florestais que rapidamente avançam sobre o campo em áreas de transição floresta-campo (Pillar e Quadros 1997, Müller et al. 2006). Estas fisionomias abertas e suas propriedades ecológicas têm sido mantidas, em grande

parte, pela utilização adequada do pastejo (Senft et al. 1987, Coughenour 1991, Pillar e Quadros 1997). Entretanto, o pastejo excessivo diminui a cobertura do solo levando à erosão e ao desaparecimento de espécies forrageiras. O manejo adequado, por outro lado, contribui para a manutenção da diversidade de espécies e grupos funcionais (Boldrini e Eggers 1996, Overbeck et al. 2007).

Quase toda a produção animal do estado é dependente de pastagens naturais constituindo importante recurso forrageiro que movimenta a principal atividade econômica da região. O mau uso do solo, manejo inadequado do campo e a perda de habitat, decorrem na extinção local de muitas espécies que desempenham importantes papéis no funcionamento deste tipo de ecossistema. Atualmente, os principais problemas e ameaças relacionados à conservação dos campos são; a expansão da produção agrícola e silvicultural, o uso de pastagens cultivadas com espécies exóticas, o pastejo excessivo, a erosão (Trindade 2003) e a baixa representatividade dos campos protegidos em unidades de conservação (Overbeck et al. 2007).

Estabilidade x complexidade e o conceito de redundância funcional

Apesar de antiga, ainda é corrente na literatura a discussão sobre a importância da diversidade na estabilidade e manutenção dos ecossistemas. Estas questões, originalmente propostas por grandes mentes, incluindo Darwin (1859), MacArthur (1955), Elton (1958), e May (1974) atualmente enfocam a importância funcional da diversidade. Isto é, na relação da diversidade com aspectos funcionais dos ecossistemas, como produtividade primária, ciclagem de nutrientes, respiração, taxa de decomposição, seqüestro de carbono, entre outros fatores (Tilman & Downing 1994, Tilman et al. 1996, Finlay et al. 1997, McGrady-Steed et al. 1997,

Wardle et al. 1997, Tilman et al. 2000). Esta relação é ainda bastante controversa (Lehman & Tilman 2000, Pfister & Chmid 2002) e tem importante implicação na conservação da biodiversidade (Tilman 1997, Chapin et al. 1997, 1998; Edwards & Abivardi 1998).

O conceito de redundância funcional foi introduzido no âmago desta discussão (complexidade x estabilidade) com a questão de quanta extinção os ecossistemas podem suportar antes de se tornarem instáveis. Nesta perspectiva, algumas espécies podem desempenhar papéis equivalentes num ecossistema (funcionalmente redundantes) e podem tornar-se localmente extintas sem causar perdas substanciais no funcionamento do ecossistema (Walker 1992, Lawton & Brown 1993).

A abordagem de grupos funcionais

A descrição de comunidades vegetais relacionando tipos fisionômicos ou formas vitais de acordo com respostas às condições ambientais remetem ao século XIX quando von Humbold, já em 1850, utilizava tipos fisionômicos usando características anatômicas, morfológicas e arquitetônicas das plantas, conforme Du Rietz (1931). Em seu “Oecology of plants” Warming (1895) buscava uma classificação das plantas superiores em grupos biológicos conforme o ambiente em que se desenvolveram, os quais denominava “*epharmonies*”. Raunkier (1934) propôs uma classificação das plantas em formas vitais baseada na posição das gemas de crescimento nas estações desfavoráveis do ano.

Modernamente, considera-se um grupo ou tipo funcional de planta como (1) um grupo de plantas que afetam de modo similar o ambiente ou (2) que apresentam uma resposta similar às variações de fatores ambientais (Díaz & Cabido, 1997,

Lavorel & Garnier, 2002, Pillar & Sosinski, 2003). Em estudos de comunidades animais, frequentemente se utiliza o termo “guilda”, mas muitos autores utilizam os termos de forma intercambiável. Esta abordagem de grupos funcionais vem sendo bastante utilizada em estudos das implicações funcionais da diversidade. Neste trabalho os grupos funcionais (herbáceas graminóides e não-graminóides) são assim definidos pela forma como exploram o espaço acima do solo em busca de luz (Wilson & Roxburg 1994) e por suas distintas características morfofisiológicas.

Experimentos de remoção e o estudo da vegetação

Grande parte dos estudos que avaliam as implicações funcionais da biodiversidade nos ecossistemas faz uso de comunidades sintéticas, a partir de grupos pré-selecionados de espécies, desprezando processos seletivos que ocorrem ao longo da história ecológica do desenvolvimento das comunidades. Muitos trabalhos já demonstraram que comunidades biológicas estão estruturadas no espaço segundo regras que delimitam como as espécies estão arranjadas, ao que se denominou *regras de montagem* (“assembly rules”, Diamond 1975) e por filtros ambientais impostos ao *pool* regional de espécies (Keddy 1992).

A manipulação de comunidades vegetais por remoção de espécies utilizada inicialmente por Clements et al. (1929) tornou-se mais popular a partir de 1970, principalmente para estudo de competição em vegetações naturalmente estabelecidas (Aarssen & Epp, 1990). Neste método, comunidades vegetais naturais podem ser simplificadas pela remoção de espécies selecionadas e dessa forma o número de espécies dentro dos tipos funcionais pode ser reduzido. A resposta dos elementos remanescentes indicará se há uma compensação destes para com a

espécie removida e se existe evidência empírica para a redundância funcional entre espécies do mesmo tipo funcional (Diaz et al. 2003).

Sobre o desenvolvimento do trabalho

Este estudo trata da relação da biodiversidade com os aspectos funcionais dos ecossistemas. Mais especificamente, de como o número de espécies afeta importantes processos ecossistêmicos tais como a produtividade primária. O primeiro capítulo “Quando os prédios desabam, as máquinas param e os ecossistemas perdem espécies: um breve ensaio sobre a teoria da redundância funcional” é um texto de caráter jornalístico e não apresenta o rigor de um artigo científico tal como os capítulos subseqüentes. Este visa elucidar o conceito de redundância funcional como característica inerente e suas consequências para qualquer tipo de sistema complexo. O segundo capítulo, “Functional redundancy in a removal experiment on grassland plant communities”, é o cerne deste trabalho. Constitui-se de um experimento no qual a biomassa aérea de espécies de diferentes grupos funcionais é removida num arranjo de tratamentos que nos possibilita averiguar se há compensação no crescimento de outras espécies do mesmo grupo funcional e se a supressão de espécies de grupos funcionais diferentes tem um menor impacto na comunidade tal como predito caso a redundância funcional seja um fator importante em comunidades campestres. O terceiro capítulo “The role of functional redundancy to grassland plant communities resistance to grazing” faz uso de um banco de dados de um experimento de pastejo previamente realizado para o desenvolvimento dos projetos de mestrado de Carolina C. Blanco (Blanco 2004) e de doutorado de Enio E. Sosinski (Sosinski 2005) para avaliar a relação da riqueza de espécies de plantas e da redundância funcional na resistência ao pastejo de comunidades campestres.

Capítulo 1 - Quando os prédios desabam, as máquinas param e os ecossistemas perdem espécies: um breve ensaio sobre a teoria da redundância funcional

Na manha do dia 16 de maio de 1968, a senhora do apartamento 90 do 18º andar do prédio residencial Ronan Point em Newman, oeste de Londres, ao ligar o fogão para esquentar seu habitual chá provocou uma pequena explosão que foi suficiente para fazer com que toda a esquina do prédio de 22 andares viesse abaixo no que os engenheiros costumam chamar de colapso progressivo. O Ronan Point era uma das construções do tipo “tower blocks” típica dos anos 60, nas quais as estruturas são pré-fabricadas e encaixadas. As paredes de um andar sustentam o piso de cima e este, por sua vez, sustenta as paredes do andar superior. A perda de uma das paredes do 18º andar foi responsável pela queda de toda a esquina do prédio. O colapso do prédio se deu por falta de **redundância** em sua estrutura (Petroski 1994, grifo nosso).



Figura 1. O colápsio do prédio residencial Ronan Point (Great Britain Department of the Environment, 1973).

Em engenharia, redundância, ou redundância estrutural é a multiplicação de elementos importantes de um sistema que aumentam sua confiabilidade quando o sistema for perturbado. Este tema tem chamado a atenção dos engenheiros com a descoberta de um grande número de falhas dos sistemas estruturais de construções em recentes terremotos (Wen 2001). Em biologia molecular tem se chamado de redundância genética, ou redundância funcional a presença de dois ou mais genes que desempenham a mesma função em um genoma. Estudos recentes mostram que a redundância genética pode alterar a composição genética de uma espécie ao longo do curso da evolução (Kochiwa et al. 2007) e que de 4000 genes apenas 300 seriam “*indispensáveis*” para a bactéria *Escherichia coli* (Baba et al. 2006). Em eletrônica, peças são adicionadas para aumentar a redundância funcional e dessa forma a confiabilidade desses sistemas.

Uma rápida busca em bancos de dados da Web-of-science (<http://portal.isiknoledge.com>), mostra que o termo “*Funcional redundancy*” é utilizado em diversas áreas do conhecimento: engenharia, bioquímica, informática, biologia molecular, medicina, neurociência, nanotecnologia, ciência da comunicação, administração, economia e ecologia. Assim, redundância funcional é uma característica de sistemas complexos no qual elementos independentes (ou interdependentes) executem as mesmas funções aumentando a confiabilidade desse sistema quando for perturbado e elementos forem perdidos.

Alguns princípios fundamentais da teoria da redundância funcional podem ser estabelecidos como:

- 1) Elementos que realizem as mesmas funções pertencem ao mesmo grupo funcional e são ditos *cofuncionais*.
- 2) Elementos cofuncionais podem ter diferentes níveis de redundância funcional caso contribuam em intensidades ou condições diferentes para uma determinada função.
- 3) Sistemas com o mesmo número de grupos funcionais, mas com maior número de elementos têm potencialmente maior redundância funcional.
- 4) Sistemas com o mesmo número de grupos funcionais e o mesmo número de elementos têm maior redundância funcional quando os elementos estão distribuídos eqüitativamente entre os grupos.
- 5) A perda de elementos de um sistema decorre, por definição, em perda de redundância funcional.
- 6) A falha, perda ou supressão de elementos é compensada pelos elementos cofuncionais remanescentes.
- 7) A perda de redundância funcional diminui a confiabilidade de um sistema, onde confiabilidade é a capacidade de um sistema em manter estáveis as demandas de suas funções e processos.

Em ecologia, espécies que contribuem da mesma forma para o funcionamento do ecossistema (produtividade primária, decomposição, ciclagem de nutrientes, entre outros processos) são consideradas funcionalmente redundantes, isto é, a perda de algumas espécies pode não afetar o funcionamento do ecossistema (Walker 1992). Isto implica no fato de

que a perda de espécies do mesmo grupo funcional é muito mais periclitante que a perda do mesmo número de espécies de grupos funcionais distintos (Lawton e Brown 1993, Fonseca e Ganade 2001). Um exemplo disso é o pastejo excessivo e inadequado em alguns campos da região da Campanha gaúcha, resultando na perda das espécies forrageiras ou até mesmo de todas as espécies do grupo funcional “graminoides”.



Figura 2. Área de campo completamente dominada por *Dicondra sericea* e a distuição completa de espécies graminoides (Foto: José Pedro Pereira Trindade).

O conceito foi estabelecido por Walker com o intuito de estabelecer prioridades para a conservação, determinando que algumas espécies seriam mais importantes para o funcionamento dos ecossistemas do que outras. Alguns autores interpretaram o termo de uma forma negativa, considerando que as espécies redundantes são *dispensáveis* para o funcionamento dos

ecossistemas (Basking 1994, Cowling et al. 1994, Bowman 1994, Kennedy & Smith 1995) e que por isso seria um conceito “perigoso” para a conservação (Richardson & Cowling 1993, Gitay et al. 1996). Alguém poderia argumentar que a extinção de espécies não é um problema tão grave, pois a maioria das espécies é supérflua.

Ora, a redundância funcional, ao contrário do que alguns poderiam pensar, não torna estas espécies *dispensáveis*, pois essas podem estar garantindo a estabilidade destes ecossistemas quando perturbados ou quando algumas espécies forem extintas, funcionando como uma espécie de “seguro” (Walker 1995, Rosenfeld 2002, Naeem 1998). Shahid Naeem em “Species redundancy and ecosystem reliability” (1998) defende o uso do conceito fazendo analogias com suas aplicações na engenharia, ressaltando seus aspectos positivos para a manutenção dos processos nos ecossistemas. Ainda neste trabalho descreve alguns modelos matemáticos da engenharia que relacionam redundância e confiabilidade de sistemas e que poderiam ser aplicados às questões ecológicas.

Entretanto, há uma limitação na comparação da redundância funcional dos sistemas da engenharia com ecossistemas. Em primeiro lugar as peças da estrutura de um prédio foram projetadas para desempenharem uma determinada função. Espécies desempenham diversas funções e o fazem porque possuem características morfofisiológicas decorrentes da adaptação ao ambiente num processo evolutivo de seleção natural. É preciso ressaltar aqui que “função” quando relacionada às espécies biológicas não implica em propósito ou “design” como ocorrem com os elementos de uma máquina ou construção. Além disso, parafusos não migram e não se reproduzem e os elementos estruturais de um prédio não invadem a estrutura do prédio vizinho.

Espécies o fazem. A estrutura de um prédio pode até se alterar um pouco devido à dilatação e contração dos materiais com a variação da temperatura, enquanto ecossistemas sofrem mudanças drásticas na conformação das comunidades biológicas de uma estação climática para outra. Redundância funcional é uma propriedade importante tanto na engenharia quanto na ecologia, mas sua avaliação é um pouco mais problemática na última. Não apenas pela falta de intimidade da maioria dos ecólogos para com a matemática, mas principalmente pela dinâmica e complexidade que envolve os sistemas biológicos.

O desconhecimento da importância da redundância funcional no Ronan Point teve como consequência um grande prejuízo econômico e a morte de quatro pessoas. O desprezo desta característica em ecossistemas pode trazer consequências ainda mais graves.



Figura 3. Degradação e arenização facilitadas pelo pastejo excessivo dos campos da Campanha gaúcha próximo aos areais de Manoel Viana (Foto: José Pedro Pereira Trindade).

REFERÊNCIAS BIBLIOGRÁFICAS

- BABA, T.; ARA, T.; HASEGAWA, M.; TAKAI, Y.; OKUMURA, Y.; BABA, M.; DATSENKO, K.A.; TOMITA, M.; WANNER, B.L.; MORI, H. Construction of Escherichia coli K-12 in-frame, single-gene knockout mutants: the Keio collection. **Mol Syst Biol**, n. 2, 0008, 2006.
- BASKIN, Y. Ecosystem function of biodiversity. **BioScience**, n.44, p. 657-660, 1994.
- BOWMAN, D. Cry shame on all humanity. **New Scientist**, n. 144, v.1952, p. 59,1994.
- COWLING, R.M.; MUSTART, PJ.; LAURIE, H; RICHARDS, M.B. Species diversity; functional diversity and functional redundancy in fynbos communities. **South African Journal of Science**, n. 90, p. 333-337, 1994.
- FONSECA, C.R.; GANADE, G. Functional redundancy, random extinctions and the stability of ecosystems. **Journal of Ecology**, n. 89, p. 118-125, 2001.
- GITAY, H.J.; WILSON, J.B.; LEE, W.G. **Species Redundancy: A Redundant Concept?** *Journal of Ecology*, n. 84, p. 121-124, 1996.
- KENNEDY, A.C. AND SMITH, K.L. Soil microbial diversity and the sustainability of agricultural soils. **Plant and Soil**, n. 170, p. 75-86, 1995.
- KOCHIWA, H. TOMITA, M. E KANAI, A. Evolution of ribonuclease H genes in prokaryotes to avoid inheritance of redundant genes. **BMC Evolutionary Biology**. n. 7, p. 128, 2007.
- LAWTON, J.H.; BROWN, V.K. Redundancy in ecosystems. In: SCHELZE, E.D.; MOONEY, H.A. (eds) **Biodiversity and ecosystem function**, Springer, Berlin Heidelberg, New Yourk, p. 255-270, 1993.
- NAEEM, S. Species redundancy and ecosystem reliability. **Conservation Biology**, n.12, p. 39-45, 1998.
- PETROSKI, H. **Design paradigms**. Cabridge University Press, Cambridge, United Kingdom. 1994.
- RICHARDSON, D.M. and Cowling, R.M. Biodiversity and ecosystem processes: opportunities in Mediterranean-type ecosystems. **Trends in Ecology and Evolution**, n. 8, p. 79-80, 1993.
- ROSENFIELD, J.S. Functional redundancy in ecology and conservation. **Oikos**, n. 98, p. 156-162, 2002.
- WALKER, B.H. Biodiversity and Ecological Redundancy. **Conservation Biology**, n. 6, p. 18-23, 1992.
- _____. Conserving biological diversity through ecosystem resilience. **Conservation Biology**, n. 9, p. 747-752, 1995.
- WEN, Y.K. Reliability and performance based disgn. **Structural safety**, n. 23, p. 407-428. 2001.

Capítulo 2 – Functional Redundancy in a Removal Experiment on Grassland Plant Communities

Summary

1. Functional redundancy predicts that some species may play equivalent roles in ecosystem functioning therefore conferring a kind of “insurance” to perturbation when species richness is reduced, by the compensation of species of the same functional group on ecosystem processes.
2. We evaluate functional redundancy on grassland plant communities by a removal experiment in which the evaluated treatments were: GG – removal of two graminoid species, FF – removal of two forb species, GF – removal of one graminoid and one forb species and Control – no removal. We tested the hypothesis that the removal of one species of each functional group would cause less change in the community composition (community persistence) and less decrease in biomass production than the removal of two species of the same functional group.
3. Functional redundancy was corroborated for community persistence since treatments FG and C caused less change in community composition than treatments GG and FF, although no differences were found between treatments for aboveground biomass. We verified that removed species tend to be compensated by an increase in the percent cover of the remaining species of the same functional group.
4. *Synthesis.* This work provides experimental evidence of functional redundancy in naturally established grassland plant communities, here highlighted as an intrinsic feature of communities insuring their reliability, as a consequence of species compensation within functional groups.

Introduction

Anthropogenic activity is causing rapid loss of species from many of Earth's ecosystems (Ehrlich & Ehrlich 1981, Wilson 1988) altering community and ecosystem properties and processes (Schulze & Mooney 1993). Biota changes due to species extinction and invasions have also altered goods and ecosystems services provided to humanity. These conclusions are well-documented in ecological literature (Hooper et. al. 2005), although, the relation of biodiversity and ecosystem functioning and its intensity is a topic of constant debate and still lacks consensus (Schulze & Mooney 1993).

The functional redundancy hypothesis predicts that some species may perform equivalent roles in important ecosystem processes so that the loss of some species may not affect ecosystem functioning (Walker, 1992; Lawton & Brown 1993). Otherwise, some disagreements and misinterpretations concern in the concept's consequences for conservation. Walker (1992) introduced the idea to determine conservation priorities on less redundant species: "the loss of some species may not be as ecologically critical as the loss of some others". Many authors have given this a negative connotation as "superfluous", "unnecessary" or "expendable" (Basking 1994, Cowling et al. 1994, Bowman 1994, Kennedy & Smith 1995); others have classified it as "dangerous" for conservation (Richardson & Cowling 1993, Gitay et al. 1996). The defenders of the concept argue that it should be interpreted positively and to instead consider redundancy as an important insurance to perturbation (Walker 1995, Rosenfeld 2002, Naeem 1998) by species compensation on ecosystem processes when diversity is reduced. It has been mathematically defined taking into account the species distribution in functional groups (Fonseca & Ganade 2001) and the amount of material or energy processed by them (Naeem 1998).

Despite misinterpretations, functional redundancy is an important hypothesis concerning biodiversity-ecosystem functioning relationship and should be evaluated as an important property of ecosystems, here defined as: *the amount or range of elements (species or functional traits) that exceeds the amount or range needed to fully support ecosystem functioning, insuring its reliability.*

Previous work has demonstrated its importance in South African fynbos (Cowling et al. 1994), alpine grasslands (Johnson & Mayeux 1992), microorganisms (Wohl et al. 2004, Jiang 2007) and seagrass beds (Duffy et al. 2001). However, studies have found no redundancy, for instance, in avian assemblages (Petchey et al. 2007), grasslands (Tilman & Downing 1994) and low redundancy on coastal marine assemblages (Fiorenza & Halpern 2005).

Functional redundancy can experimentally be demonstrated by species removal experiments (Walker 1992, Díaz et al 2003) in which species are classified into functional groups and then species or sets of species are removed from assemblages changing its composition. Functional redundancy may then be demonstrated by species compensation (i.e. locally extinct redundant species are compensated by others species from the same functional group).

In this paper we make use of a removal experiment in a south Brazilian grassland to: (1) Assess the functional role of species richness on above ground biomass and plant percent cover; and (2) evaluate functional redundancy by species compensation on community biomass and changes in species composition (a measure of community persistence) due to species aboveground biomass removal.

Methods

STUDY SITE

The experimental site was situated on a 50 ha southern Brazilian grassland area at the Estação Experimental Agronômica of Universidade Federal do Rio Grande do Sul ($30^{\circ}05'27"S$, $51^{\circ}40'18"W$) in the central depression of Rio Grande do Sul Province. The climate is subtropical and moist and mean annual rainfall is 1440 mm^{-1} year. Month mean temperature ranges from 9.0°C in cold periods (June and July) to 25.6°C in summer (January and February). Natural vegetation is constituted mainly by grasslands, interspersed by gallery forests along water creeks. The site had been grazed by cattle until the beginning of the experiment in November of 2006 and was suppressed during the whole experiment. The grassland was 3-6cm high with interspersed high tussocks (some grass species individuals rejected by cattle) spread over the area.

EXPERIMENTAL DESIGN

Thirty six blocks of $0.5 \times 0.5\text{m}$ subdivided into four $0.2 \times 0.2\text{m}$ plots (one in each corner, separated by a 10cm border) were distributed over the area. Blocks were at least, twenty metres apart from each other, avoiding tussocks and maintaining homogeneity within. Permanent iron pegs were placed in two diagonally opposite corners of each block and a $0.5 \times 0.5\text{m}$ metal frame was used to relocate the blocks and plots with considerable accuracy. In November 2006 vegetation was evaluated in order to assess composition of species and species percent covers (see below). Plant species were grouped into two general functional groups: graminoids and forbs (Table 1). A removal experiment was conducted to test for functional redundancy by species

compensation in community composition and total aboveground biomass. We evaluated the hypothesis that the removal of one species from each functional group would cause less harm in community composition and aboveground biomass production than the removal of two species of the same functional group. Within each block four treatments were randomly distributed among plots: GG - removal of two graminoid species; FF- removal of two forb species; GF- removal of one graminoid and one forb species and C- Control (no removal).

Table 1. List of identified plant species found during the experiment classified into functional groups. Nine graminoids and seventeen forbs were not clearly identified. Species clipped in some plots for the application of treatments are presented in bold type.

Functional group	Species
Graminoids	<i>Abildgaardia ovata</i> , <i>Andropogon lateralis</i> , <i>Andropogon selloanus</i> , <i>Aristida laevis</i> , <i>Aristida venustula</i> , <i>Axonopus affinis</i> , <i>Brisa subaristata</i> , <i>Bulbostylis capillaries</i> , <i>Coelorachis selloana</i> , <i>Cynodon sp.</i> , outras Cyperaceae, <i>Danthonia secundiflora</i> , <i>Elyonurus sp.</i> , <i>Eragrostis neesii</i> , <i>Eragrostis plana</i> , <i>Fimbristylis diphylla</i> , <i>Fimbristylis sp.</i> , <i>Kynllinga vaginata</i> , <i>Panicum bergii</i> , <i>Panicum sabulorum</i> , <i>Paspalum maculosum</i> , <i>Paspalum notatum</i> , <i>Paspalum paucifolium</i> , <i>Paspalum plicatulum</i> , <i>Paspalum pumilum</i> , <i>Piptochaetium montevidense</i> , <i>Piptochaetium stipoides</i> , <i>Rhynchospora tenuis</i> , <i>Sacciolepis vilvoidea</i> , <i>Schizachyrium spicatum</i> , <i>Scleria distans</i> , <i>Setaria parviflora</i> , <i>Sporobolus indicus</i> .
Forbs	<i>Aeschynomene falcata</i> , <i>Aspilia montevidensis</i> , <i>Baccharis trimera</i> , <i>Borreria brachystemonooides</i> , <i>Borreria eryngioides</i> , <i>Borreria verticillata</i> , <i>Centella asiatica</i> , <i>Chaptalia runcinata</i> , <i>Chevreulia acuminata</i> , <i>Chevreulia sarmentosa</i> , <i>Cliococca selaginoides</i> , <i>Clitoria nana</i> , <i>Conyza primulifolia</i> , <i>Conyza bonariensis</i> , <i>Crotalaria tweediana</i> , <i>Cuphea glutinosa</i> , <i>Desmanthus tatusiensis</i> , <i>Desmodium incanum</i> , <i>Dichondra sericea</i> , <i>Diodia apiculata</i> , <i>Eryngium ciliatum</i> , <i>Eryngium horridum</i> , <i>Euphorbia selloi</i> , <i>Evolvulus sericeus</i> , <i>Facelis retusa</i> , <i>Galactia marginalis</i> , <i>Galianthe fastigiata</i> , <i>Gamochaeta americana</i> , <i>Glandularia megapotamica</i> , <i>Gratiola peruviana</i> , <i>Helianthemum brasiliense</i> , <i>Hidrochotyle exigua</i> , <i>Hybanthus bicolor</i> , <i>Kropovickasia macrodon</i> , <i>Mecardonia tenella</i> , <i>Noticastrum decumbens</i> , <i>Oxalis sp.</i> , <i>Oxalis conorrhiza</i> , <i>Oxalis eriocarpa</i> , <i>Peltodon longipes</i> , <i>Pfaffia tuberosa</i> , <i>Piriqueta selloi</i> , <i>Plantago myosuros</i> , <i>Podocoma hirsuta</i> , <i>Polygonum limoides</i> , <i>Poligala pulmila</i> , <i>Polygala adenophylla</i> , <i>Psidium luridum</i> , <i>Pteurocaudon sp.</i> , <i>Rebutium richardianum</i> , <i>Richardia brasiliensis</i> , <i>Richardia grandiflora</i> , <i>Richardia humistrata</i> , <i>Richardia stellaris</i> , <i>Ruellia morongii</i> , <i>Sida rhombifolia</i> , <i>Sisyrinchium sp.</i> , <i>Stellaria media</i> , <i>Stevia aristida</i> , <i>Stylosanthes leiocarpa</i> , <i>Stylosanthes montevidensis</i> , <i>Tibouchina gracilis</i> , <i>Turnera sp.</i> , <i>Vernonia flexuosa</i> , <i>Vernonia megapotamica</i> , <i>Vernonia nudiflora</i> , <i>Vernonia sekowii</i> , <i>Wahlenbergia linarioides</i> , <i>Zornia reticulata</i> .

VEGETATION ASSESSMENT AND SPECIES REMOVAL

Before treatments distribution, vegetation was assessed non-destructively in each 0.2 x 0.2m plot by visual percent cover estimation in the following categories: 1%, 5% and in intervals of 10% from 10 to 100. Species to be removed in each plot were then determined considering the following eligible criteria: 1. Plot treatment and species functional group (ex: in GG treatment plots both removed species should be graminoids); 2. Percent cover: removed species should present at list 5% of cover, but dominant species were preferable; 3. Identity variability: sub-dominant species were sometimes chosen for removal (instead of dominant) in order to achieve generalization power on functional groups responses and avoid hidden treatment problems (Huston 1997), such as the effect of a dominant species instead of a functional group. In a total of 216 removals, 48 species were fairly evenly chosen (Table 1). Chosen species were removed by aboveground clipping in February 2007 for treatments application, which were maintained by clipping on May and October 2007. Removed biomass was oven-dried by 70°C by one week and weighed in order to be evaluated later as a covariate of treatment effect. On December 2007 we assessed vegetation by evaluating species percent covers again. Total aboveground biomass was then removed by 0 – 1 cm clipping, oven-dried (70°C by one week) and weighed.

THE REMOVAL RESPONSE COEFFICIENT

Functional group compensation to species removal was evaluated by a removal response coefficient adapted from Silander & Antonovics (1982), $C(ij)A = N(ij)A / N(ij)$, where $N(ij)$ is the total percent cover of both removed species (i and j) before their removal and $N(ij)A$ is the total amount of increase (or

decrease) in percent cover of the remaining species of functional group A following the removal of i and j. Here we attempt to measure the intensity of competition experienced by species of a functional group A due to removal of two species (i and j) of the other functional group (competition between functional groups) as well as the competition experienced by species of a functional group A due to removal of two species (i and j) of the same functional group (competition within functional groups).

DATA ANALYSIS

Responses of community composition change and aboveground biomass to removal treatments were analyzed by using analyses of variance in a block design with permutation tests (Pillar & Orlóci 1996) with 10,000 permutations, implemented on the application MULTIV (Pillar 2005). Changes in composition were measured by the chord distance between initial and final state of community species percent covers. Clipped biomass was taken as a covariate and was removed before analyses of variance by using residuals of predictive and predictor variables to this covariate.

Relationships of species richness with total aboveground biomass and total percent cover of plants was evaluated by linear regression models considering only control plots. A paired student t test was used to evaluate the difference of species richness from the beginning to the end of the experiment followed by an analysis of variance to evaluate differences among treatments. Relative increment of percent cover of graminoids and forbs among treatments were evaluated by analysis of variance. Differences within and between functional groups responses to removal of species (removal response coefficients) were tested with analyses of variance via permutation tests with

10,000 permutations on MULTIV, by comparing treatments GG and FF on remaining species responses.

CAUTION ON REMOVAL EXPERIMENT RESPONSES INTERPRETATION

Removal experiments have recently been deemed as the best approach to study the role of diversity on ecosystem functioning (Díaz et. al. 2003), however some cautions must be taken with artifactual effects (Aarssen & Epp 1990, Huston 1997 and Díaz et. al. 2003) .e.g. identity of removed species, effect of the remaining bellow ground parts, for instance. In this work we are mainly interested in local species aboveground competition for space by the vegetative growth of remaining species on early responses after treatment application in small spatial scale plots. Thus we chose not to use herbicides nor manual removal of belowground plant parts as the former leaves unknown residuals and the latter disturbs the soil environment (Aarssen & Epp 1990).

Results

During the experiment a total of 108 species from 26 families were identified, 74 forbs and 34 graminoid species. Some Cyperaceae species could not be distinguished during field work and were classified in a single identity as “other Cyperaceae” and 5 forbs and 1 graminoid could not be determined. Species richness in 0.2 x 0.2m control plots ranged from 4 to 18 species and increased, on average, from 9.4 to 10.9 species during the experiment ($t = 4.45$, paired, $N = 36$, $P < 0.0001$). However, this increment did not varied between treatments ($P = 0.21$). Furthermore, species richness and aboveground biomass were not

related ($R^2 = 0.04$, $P = 0.219$) and species richness showed no relationship with total plant percent cover ($R^2 = 0.01$, $P = 0.56$).

EFFECT OF SPECIES REMOVAL ON COMPOSITION CHANGE AND ABOVEGROUND BIOMASS

The amount of biomass clipped for the experiment application was different between treatments ($P = 0.0001$). More biomass was clipped where two graminoids were removed (approximately 5.3 g per plot) followed by treatments GF (4.3 g), FF (2 g) and Control (in which, by definition no biomass was clipped). For this reason, this removed biomass was taken as a covariate to evaluate the final aboveground biomass and the change in species composition to achieve differences between treatments despite differences due to clipped biomass. No differences were found on aboveground biomass (Fig. 1a) produced during the experiment between treatments ($P = 0.442$). Changes in community composition measured by chord distances (Fig. 1b) differed between treatments ($P = 0.0486$). As stated by our hypothesis less change was observed when one species of each functional group (treatments GF) were clipped than when two species of graminoids or two species of forbs were removed ($P = 0.0141$), besides there was no difference whether two graminoids or two forb species were removed ($P = 0.3365$). Nevertheless, control plots were not different from the other treatments ($P = 0.3307$).

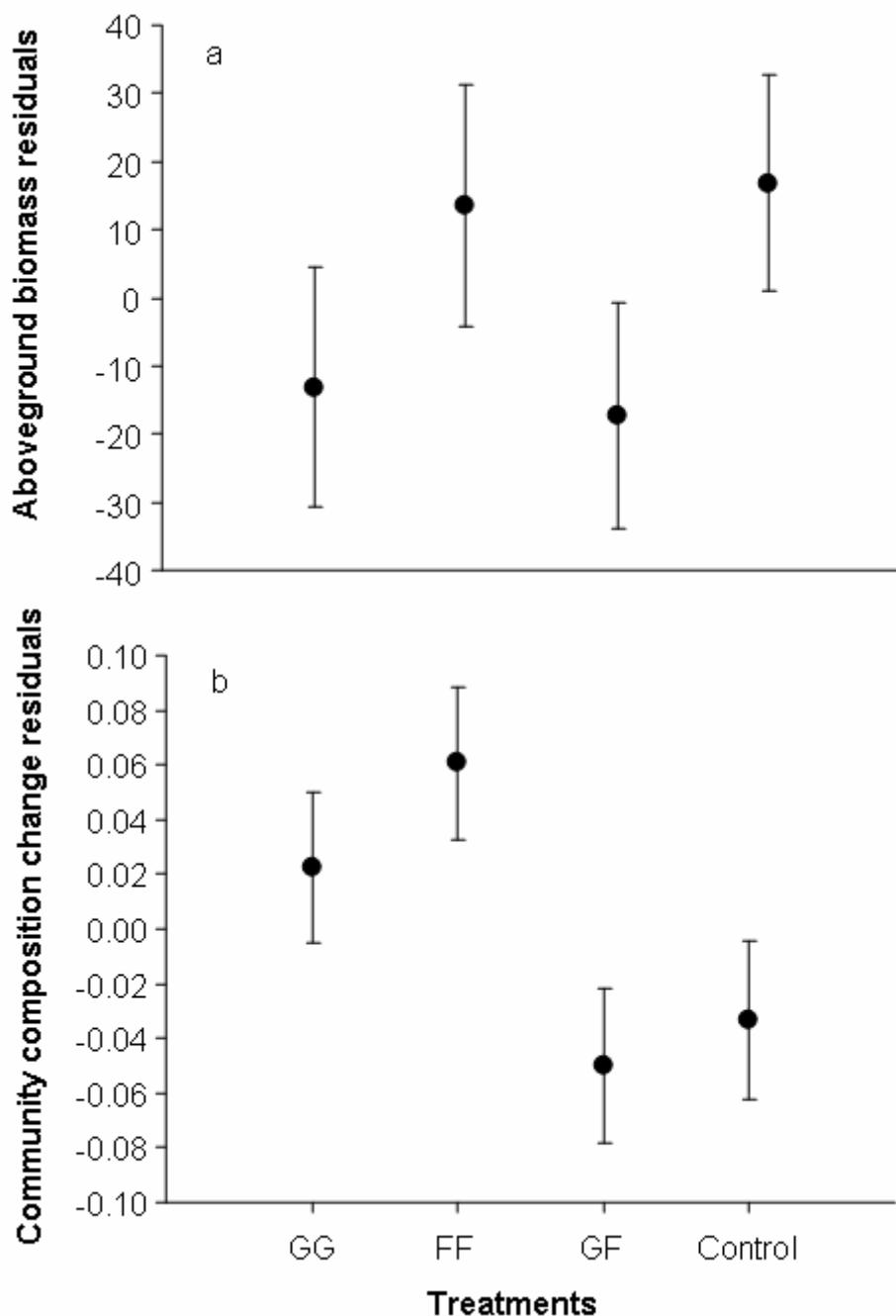


Fig. 1. Mean and standard errors ($n= 36$) of residuals of the analysis on the effect of clipped biomass in the species removal treatments on (a) aboveground biomass and (b) community composition change measured by chord distance. Treatments were: GG – removal of two graminoid species, FF – removal of two forb species, GF – removal of one graminoid and one forb species and Control – no removal.

SPECIES LOSS COMPENSATION AND THE REMOVAL RESPONSE COEFFICIENT

The effect of species removal was evaluated on the proportional increment of remaining species percent covers. An increase in all treatments was observed due to the suppression of grazing during the experiment. Differences were found between treatments on remaining graminoid species ($P = 0.0013$) and on remaining forb species ($P = 0.0001$). Remaining graminoids percent cover (Fig. 2a) increased by 108% when two graminoids were removed (treatment GG), 90% more than the increment of graminoids when two forbs were removed ($P = 0.0014$) and 85% more than the control treatment ($P = 0.0021$), suggesting a compensation for the lost graminoid species by an increment on percent cover of the remaining graminoids. When one species of each functional group (treatment GF) were removed, remaining graminoid species increased by 49%, not significantly different from any other treatment.

Remaining forbs percent cover (Fig. 2b) increased by 154% when two forb species were removed (treatment FF), contrasting to the 14% in control plots ($P = 0.0001$). The increment of remaining forb species were 87% lower in treatment GF ($P = 0.0035$) and 118% lower in treatment GG ($P = 0.0001$) than in treatment FF.

Removal response coefficients (Fig. 3) measured for graminoid remaining species presented no differences whether graminoids or forbs were removed ($N = 72$, $P = 0.635$). For remaining forb species, otherwise, removal coefficients were higher for forb species than for graminoids treatment removal ($N = 72$, $P = 0.0004$).

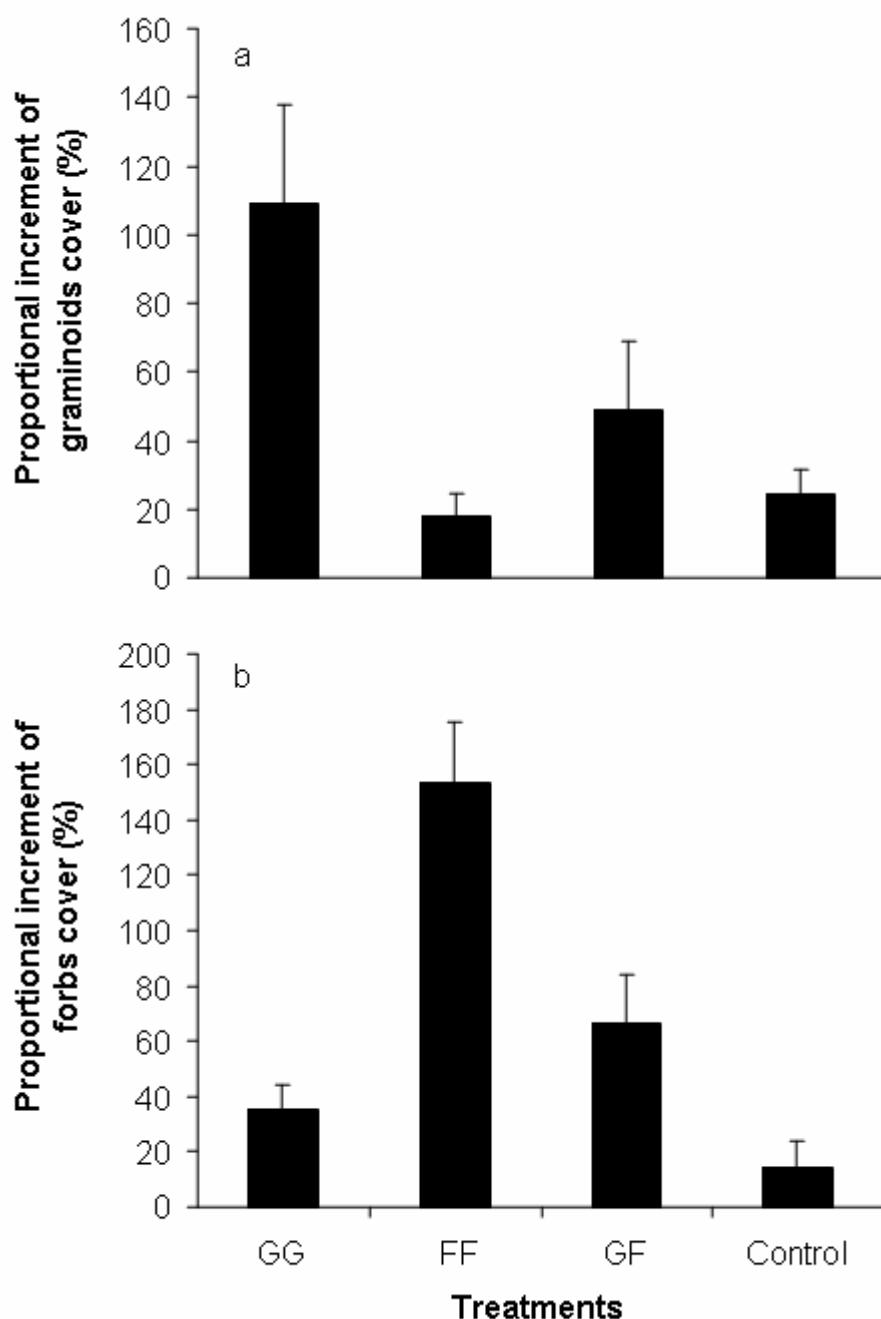


Fig. 2. Mean and standard error over 36 replicates of the proportional increment of percent cover (increment / initial percent cover) of (a) remaining graminoid species and (b) remaining forb species in response to removal treatments; GG – removal of two graminoid species, FF – removal of two forb species, GF – removal of one graminoid and one forb species and Control – no removal.

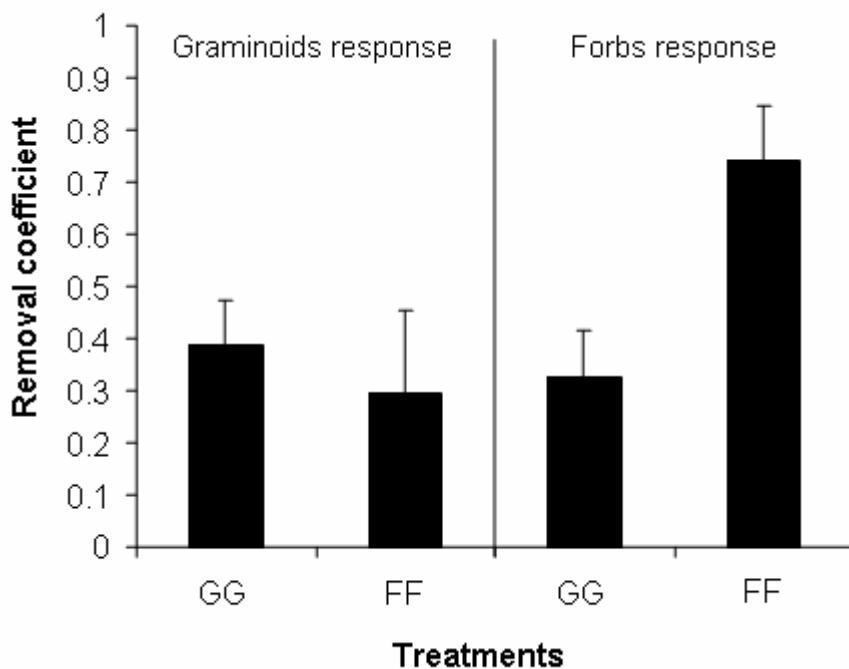


Fig. 3. Competition between and within functional groups measured by removal response coefficient (mean and standard error over 36 replicates) in response to removal of two graminoid species (GG) and two forb species (FF) on graminoid standing species and on forb standing species.

Discussion

Functional redundancy implies (1) limitations on how species diversity relates to ecosystem processes such as primary production and (2) compensation within functional groups on species loss, maintaining the ecosystem function. In our study no relationship was found between plant species richness and aboveground biomass. Such a pattern might occur by primary control of abiotic factors, dominance of ecosystem effects by dominant species or by niche overlap (Vitousek & Hooper 1993, Petchey 2000, Fridley 2001) and perhaps by functional redundancy. Previous studies, otherwise, have shown that primary production, generally surrogated by aboveground biomass,

is positively correlated with species richness (Tilman & Downing 1994, Naeem et al. 1996, Tilman et al. 1996, Hector et al. 1999, Pfisterer & Schmid 2002, Hooper et al. 2005, Roscher et al. 2007). Some authors have initially related a lack of relationship to species-redundancy hypothesis (Tilman & Downing 1994) where many species are similar concerning to ecosystem functioning in contrast to the insurance hypothesis which states that more diverse ecosystems are more likely to contain species that can respond to ecosystem disturbance. In the other hand, functional redundancy may be more likely to occur (or matter) in more diverse ecosystems (Hooper et al. 2005) since redundancy requires diversity. Positive saturating responses between diversity and functioning, is expected for both: diversity-stability hypothesis (Tilman & Downing 1994, Hooper et al. 2005) and functional redundancy hypothesis (Naeem 1998). Thus, functional redundancy should not be evaluated merely by looking at diversity-functioning graphs. It would require analyzing species compensation and experimental approaches.

Removal experiments are the best approach to evaluate functional redundancy by species compensation (Walker 1992, Lawton & Brown 1993) and allowed important questions to be addressed (Díaz et al. 2003); however some limitations have been pointed out (Gitay et al. 1996). Conclusions on redundancy may depend on functional groups definition and on which criterion was used to measure how much communities change due to removal responses. Furthermore, conclusions on functional redundancy depend on response variables considered (Duffy 2001). In this work we evaluated functional redundancy for graminoids and forbs considering the aboveground biomass (as surrogate for productivity) and the community composition change as the response variables. Our results showed that removal of two species of

the same functional group would not reduce community aboveground biomass more than removal of one species from two different functional groups; hence there is no evidence of functional redundancy for this process. Although, the converse, that functional redundancy has any affect on aboveground biomass should not be concluded. Community persistence (evaluated by the change in community composition) otherwise, changed more when the two removed species were from the same functional group than when they were from different functional groups corroborating functional redundancy for community composition change. Experimental deletions of crustacean species, for instance, demonstrated functional redundancy on epiphyte grazing and eelgrass biomass accumulation (Duffy et al. 2001). In a Canadian Shield lake, primary production was not affected by changes in species richness and composition of phytoplankton due to experimental acidification (Schindler et al. 1986). In grasslands, Fowler (1981) has shown that removal of individual species did not affect remaining plant species richness, but instead species abundances.

These responses are assumed to be a result of species compensation within functional groups (Walker 1993). Our results showed that, when evaluating proportional increment of species percent cover, the loss of species was compensated by remaining species of the same functional group, for both, graminoids and forbs. Functional redundancy has already been realized by density compensation for microbial communities (Jiang 2007); furthermore, species compensation has been reported for perennial grasslands (Wardle et al. 1999) and soil organisms (Bradford et al. 2002, Liiri et al. 2002). Many works have demonstrated that ecosystem processes depend on species composition and that the effect of species loss would depend on species identity (Naeem et

al. 1996, Wardle et al. 1999, O'Connor & Crowe 2005, Rosecher et al. 2007) and that effect of species loss conclusions on species compensation depends on response timing of remaining species (O'Connor & Crowe 2005).

The removal response coefficient, a measure of the interaction strength between removed and remaining species (Silander & Antonovics 1982, Aarssen & Epp 1990) showed that competition within forbs were greater than between forb and graminoid species and within graminoids. Compensation within forb species seems to be an outcome of competition within them. Competition within graminoids does not seem to be higher than graminoids-forbs competition and thus would not explain the large proportional increment on remaining graminoids percent cover.

As species removal effects on aboveground biomass production was not apparent, we concluded that there is no strong evidence to confirm redundancy for this process. Although, we verified functional redundancy among species by intra-functional group compensation on species removal. Removal of one species of each functional group caused less change in community composition than removal of two species from the same functional group.

Functional redundancy, despite disagreements and misinterpretations, is an important feature of communities that constrains diversity-ecosystem functioning relationships for some processes. It is a valuable concept to understand how resilient ecosystems are to perturbations.

Acknowledgements

We thank Gabriele Zimmer, João L. Carraro, Maximiliano de Oliveria, André F. Barbosa, and Marcel Tust for providing help on field work. Ilisi Boldrini, Alessandra Fidelis, Angelo A. Schneider and Rafael Trevisan greatly contributed for species identification. EMBRAPA Pecuária Sul financially supported project costs and F.J was fully supported by CAPES.

References

- Aarsen, L.W. & Epp, G.A. (1990) Neighbour manipulations in natural vegetation: a review. *Journal of Vegetation Science*, **1**, 13-30.
- Baskin, Y. (1994) Ecosystem function of biodiversity. *BioScience*, **44**, 657-660.
- Bowman, D. (1994) Cry shame on all humanity. *New Scientist*, **144**, (1952), 59.
- Bradford, M.A. Jones, T.H. Bardgett, R.D. Black, H.I.J. Boag, B. Bonkowski, M. Cook, R. Eggers T. Gange, A.C. Grayston, S.J. Kandeler, E. McCaig, A.E. Newington, J.E. Prosser, J.I. Setälä, H. Staddon, P.L. Tordoff, G.M. Tscherko, D. Lawton J.H. (2002) Impacts of soil fauna community composition on model grassland ecosystems. *Science*, **298**, 615-618.
- Cowling, R.M. Mustart, P.J. Laurie, H. Richards, M.B. (1994) Species diversity; functional diversity and functional redundancy in fynbos communities. *South African Journal of Science*, **90**, 333-337.
- Díaz, S. Symstad, A.J. Chapin, III, F.S. Wardle, D.A. Huenneke, L.F. (2003) Functional diversity revealed by removal experiments. *Trends in Ecology and Evolution*, **18**, 140-146.
- Duffy, J.E. MacDonald, K.S. Rhode, J.M. Parker, J.D. (2001) Grazer diversity, functional redundancy, and productivity in seagrass beds: an experimental test. *Ecology*, **82**, 2417-2434.
- Ehrlich, P. & Ehrlich, A. (1981) *Extinction: The Causes and Consequences of the Disappearance of Species*. Victor Gollancz, London.
- Fonseca, C.R. Ganade, G. (2001) Functional redundancy, random extinctions and the stability of ecosystems. *Journal of Ecology*, **89**, 118-125.
- Fowler, R.M. Mustart, P.J. Laurie, H. Richards, M.B. (1994) Species diversity; functional diversity and functional redundancy in fynbos communities. *South African Journal of Science*, **90**, 333-337.
- Fridley, J.D. (2001) The influence of species diversity on ecosystem productivity: how, where and why? *Oikos*, **93**, 514-526.
- Gitay, H.J. Wilson, J.B. Lee, W.G. (1996) Species Redundancy: A Redundant Concept? *Journal of Ecology*, **84**, 121-124.
- Hector, A. et al. (1999) Plant diversity and productivity experiments in European grasslands. *Science*, **286**, 1123-1127.
- Hooper, D.U. Chapin III, F.S. Ewel, J.J. Hector, A. Inchausti, P. Lavorel, S. Lawton, J.H. Lodge, D.M. Loreau, M. Naeem, S. Shmid, B. Setälä, A.J. Symstad, A.J. Vandermeer, J. Wardle, D.A. (2005) Effects of biodiversity on ecosystem

- functioning: a consensus of current knowledge. *Ecological Monographs*, **75** v.1, 3-35.
- Huston, M.A. (1997) Hidden treatments in ecological experiments: re-evaluating the ecosystem function of biodiversity. *Oecologia*, **110**, 449-460.
- Jiang, L. (2007) Density compensation can cause no effect of biodiversity on ecosystem functioning. *Oikos*, **116**, 324-334.
- Johnson, H.B. Mayeux, H.S. (1992) A view on species additions and deletions and the balance of nature. *Journal of Range Management*, **45**, 322-333.
- Kennedy, A.C. & Smith, K.L. (1995) Soil microbial diversity and the sustainability of agricultural soils. *Plant and Soil*, **170**, 75-86.
- Lawton, J.H. & Brown, V.K. (1993) Redundancy in ecosystems. *Biodiversity and ecosystem function* (eds. E.D. Schelze & H.A. Mooney), pp. 255-270, Springer-Verlag, Berlin.
- Liiri, M. Setälä, H. Haimi, J. Pennanen T. Fritze, H. (2002) Relationship between soil microarthropod species diversity and plant growth does not change when the system is disturbed. *Oikos*, **96**, 137-149.
- Naeem, S. Hakansson K. Lawton, J.H. Crauley M.J. Thompson. (1996) Biodiversity and plant productivity in a model assemblage of plant species. *Oikos*, **76**, 259-264.
- Naeem, S. (1998) Species redundancy and ecosystem reliability. *Conservation Biology*, **12**, 39-45.
- O'connor, N.E. & Crowe, T. (2005) Biodiversity and ecosystem functioning: distinguishing between number and identity of species. *Ecology*, **86**, 1783-1796.
- Petchey, O.L. Evans, K.L. Fishburn I.S. Gaston, K. (2007) Low functional diversity and no redundancy in British avian assemblages. *Journal of Animal Ecology*, **76**, 977-985.
- Pfisterer, A.B. Schmid, B. (2002) Diversity-dependent production can decrease the stability of ecosystem functioning. *Nature*, **416**, 84-86.
- Pillar, V.D. (1994-2005) **MULTIV**, software for multivariate exploratory analysis, randomization testing and bootstrap resampling (for Macintosh and Windows). Departamento de Ecologia, UFRGS, Porto Alegre.
- Pillar, V.D. Orlóci L. (1996) On randomization testing in vegetation science: multifactor comparisons of relevé groups. *Journal of Vegetation Science*, **7**, 585-592.
- Petchey, O.L. (2000) Species diversity, species extinction, and ecosystem function. *American Naturalist*, **155**, 696-702.

- Richardson, D.M. & Cowling, R.M. (1993) Biodiversity and ecosystem processes: opportunities in Mediterranean-type ecosystems. *Trends in Ecology and Evolution*, **8**, 79-80.
- Rosenfeld, J.S. (2002) Functional redundancy in ecology and conservation. *Oikos*, **98**, 156-162.
- Roscher, C. Schumacher, J. Weisser, W. Schmid, B. Schulze, E. (2007) Detecting the role of individual species for overyielding in experimental grassland communities composed of potentially dominant species. *Oecologia*, **154**, 535-549.
- Silander, J.A. & Antonovics J. (1982) Analysis of interpecific interactions in a coastal plant community – a perturbation approach. *Nature*, **298**, 557-560.
- Schulze, E.D. & Mooney, H.A. (Eds.) (1993) *Biodiversity and Ecosystem Function*. Springer-Verlag, Berlin.
- Tilman, D. Downing, J.A. (1994) Biodiversity and stability in grasslands. *Nature*, **367**, 363-365.
- Tilman, D. Wedin, D. Knops, J. (1996) Productivity and sustainability influenced by biodiversity in grassland ecosystems. *Nature*, **379**, 718-720.
- Vitousek, P.M. Hooper, D.U. (1993) Biological diversity and terrestrial ecosystem biogeochemistry. *Biodiversity and Ecosystem Function*. (eds E.D. Schulze & H.A. MOONEY), pp 3-14, Springer-Verlag, Berlin.
- Walker, B.H. (1992) Biodiversity and Ecological Redundancy. *Conservation Biology*, **6**, 18-23.
- Walker, B.H. (1995) Conserving biological diversity through ecosystem resilience. *Conservation Biology*, **9**, 747-752.
- Wardle, D.A. Bonner, K.I. Barker, G.M. Yeates, G.W. Nicholson, K.S. Bardgett, R.D. Watson, R.N. Ghani, A. (1999) Plant removals in perennial grassland: vegetation dynamics, decomposers, soil biodiversity, and ecosystem properties. *Ecological Monographs*, **69**, 535-568.
- Wilson, E.O. (1988) *Biodiversity*. Macmillan, New York, 1988.
- Wohl, D.L. Satyam, A. Gladstone, J.R. (2004) Functional redundancy supports biodiversity and ecosystem function in a closed ands constant environment. *Ecology*, **85**, 1534-1540.

Capítulo 3 - The Role of Functional Redundancy to Grassland Plant Community Resistance to Grazing

INTRODUCTION

Species loss resulting from human global impact on Earth's ecosystems is of general concern in scientific literature (Hooper et. al. 2005). This global loss of diversity affects ecosystem processes linked to important goods and services provided to human sustainability as food, fodder, fuel, carbon sequestration, water supply and weather constancy (Chapin et. al. 2000, Díaz & Cabido 2001). However, the relation of biodiversity to ecosystem functioning and its intensity is a topic of constant debate and still lacks consensus (Schulze & Mooney 1993).

These biodiversity-ecosystem functioning studies revisit the old debate over ecosystem complexity and stability (MacArthur 1955, Elton 1958, May 1974, Pimm 1991). Current hypotheses predict that more diverse ecosystems may resist changes in processes due to perturbations or would present greater resilience by returning to its state before perturbation. The insurance hypothesis of biodiversity (Yachi & Loreau 1999) predicts that resistance and resilience should increase with species richness because a greater number of species would guarantee a greater range of responses to perturbation by increasing performance of non-dominant species.

Functional redundancy, otherwise, predicts a constrained relation of species richness to ecosystem processes in which different species perform the same functional role in ecosystems so that the loss of same species may not affect functioning (Walker 1992, Lawton & Brown 1993). Some authors have given a

negative connotation to the concept in the sense that redundant species are “expandable” (Basking 1994, Cowling et. al. 1994, Bowman 1994, Kennedy & Smith 1995), meanwhile it should be considered as an insurance to perturbation (Walker 1995, Rosenfeld 2002) and a critical feature affecting ecosystem reliability (Naeem 1998). Therefore, functional redundancy, better than species richness may enhance resistance and resilience of ecosystems.

The diversity-stability relation still lacks experimental direct evidence (Pfisterer & Schmid 2002), furthermore, the majority of experiments are conducted in artificially assembled communities (Tilman & Downing 1994, Pfisterer & Schimdt 2002, Tilman et al. 2006) instead of natural grasslands which have been driven by ecological history.

In southern Brazilian grasslands overgrazing is a frequent disturbance that drastically affects pasture productivity (Nabinger et al. 2000) and soil cover, changing its physiognomy, composition and diversity (Overbeck et al. 2007). These grasslands named “Campos” in Brazil have long been neglected as an important biome by environmental policies and scientific research (Overbeck et al. 2007, Fidelis et al. 2008). In this work we attempt to evaluate the role of functional redundancy to grassland resistance to cattle grazing.

METHODS

The field site is a natural grassland area of three hectares in the Estação Experimental Agronômica of the Universidade Federal do Rio Grande do Sul – UFFRGS, (30°05'49"S, 51°41'14"W) in south Brazil. The climate is subtropical and moist and mean annual rainfall is 1440 mm/year. Natural vegetation is constituted

mainly by grasslands, interspersed by gallery forests along water creeks. Twenty plots of 0,2 x 1m were systematically distributed over the area. In February of 2002 the area was submitted to cattle grazing by 54 female calf during 17 days. Community composition and species percent cover were assessed in each quadrat by visual estimation before and after the grazing period. Species found were classified into four functional groups (Table 1) based on life form and aboveground spatial exploring strategy: Caespitose graminoids (grasses and Cyperaceae with erect leaf laminas), prostrated (prostrated and stoloniferous grasses and forbs), rosettes (prostated forbs with radial symmetry) and non-prostrated forbs.

Grassland community resistance to cattle grazing was measured by Sorenson similarity index considering presence and absence of species in communities (Palmer & White 1994) i.e. a measure of how less change has occurred within community after grazing. The greater the similarity index the less the community has changed and thus, the greater the resistance. Functional redundancy was measured by the number of species per functional group before grazing, thus communities with more species within functional groups have a greater functional redundancy level (Fonseca & Ganade 2001).

Relationships between species richness, diversity and functional redundancy levels and community resistance to grazing were evaluated by simple regression models and the relation between functional redundancy and resistance despite species richness was evaluated by comparing models taking richness as a covariate, on the R console.

Table 1. List of identified plant species found during the grazing experiment classified into functional groups.

Functional group	Species
Caespitouse graminoids	<i>Agrostis montevidensis, Andropogon lateralis, Aristida laevis, Briza subaristata, Briza uniolae, Bulbostylis juncoides, Calamagrostis vividiflavesrens, Coelorachis selliana, Cyperus polystachyos, Cyperus sesquiflorus, Eleocharis glauco-virens, Eleusine indica, Eragrostis bahiensis, Eragrostis lugens, Eragrostis neesii, Eragrostis polytricha, Eragrostis sp, Fimbristilis autumnalis, Fimbristylis diphyla, Fimbristylis miliaceae, Hypoxis decumbens, Leptochoryphium lanatum, Leptochoryphium sp., Panicum hians, Panicum sabulorum, Paspalum ionanthum, Paspalum plicatulum, Paspalum pumilum, Paspalum sp., Paspalum urvillei, Piptochaetium montevidensis, Rhynchospora tenuis, Saciolepis viloides, Scleria hirta, Schizachyrium microstachyum, Schizachyrium tenerum, Setaria geniculata, Setaria vaginata, Sporobolus indicus</i>
Prostated	<i>Axonopus affinis, Centella asiatica, Cynodon dactylon, Cyperus brevifolius, Drymaria cordata, Ischaemum minus, Oxalis sp., Paspalum notatum</i>
Rosettes	<i>Borreria verticillata, Chevreulia acuminata, Chevreulia sarmentosa, Elephantopus mollis, Eryngium horridum, Ruellia morongii</i>
Non-prostated forbs	<i>Aspilia montevidensis, Baccharis trimera, Clitoria nana, Cuphea glutinosa, Desmodium adscendens, Desmodium incanum, Eugenia uniflora, Evolvulus sericeus, Galactia marginalis, Pfaffia tuberosa, Poligala sp., Pterocaulon sp., Stylosanthes leiocarpa, Stylosanthes motevidensis, Tibouchina gracilis, Turnera selloi, Vernonia nudiflora</i>

RESULTS

Vegetation assessment presented 70 species. The most common species were *Andropogon lateralis, Paspalum notatum, Paspalum plicatulum, Desmodium incanum, Coelorachis selliana, Axonopus affinis, Fimbristylis diphyla* and *Hypoxis*

decumbens. Species richness increased from 12 to 14 species after grazing ($N = 40$, $t = 2.09$ $P = 0.001$, paired).

Initial species richness was not related to resistance on composition changes due to cattle grazing (Figure 1; $R^2 = 0.058$ $p = 0.30$). However, when species were grouped into four functional groups, community resistance to grazing increased with the number of species per functional group (functional redundancy) (Figure 2; $y = 0.0648x + 0.5716$; $R^2 = 0.41$ $p = 0.002$). Furthermore, interaction of species richness and functional redundancy was not significant *i.e.* the effect of functional redundancy on resistance was independent from the number of species.

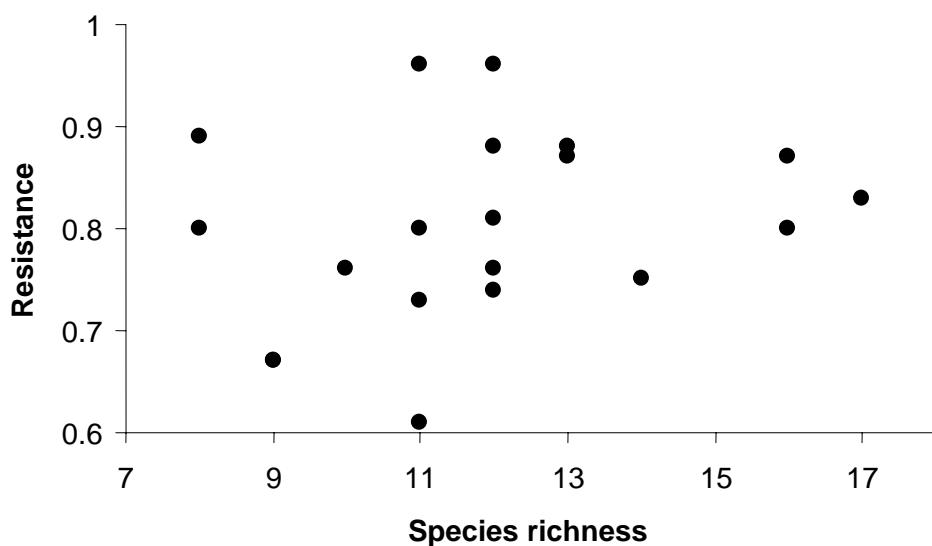


Figure 1. Relation of initial species richness to resistance on composition change (Sorenson index between final and initial states based on presence and absence of species) duo to cattle grazing.

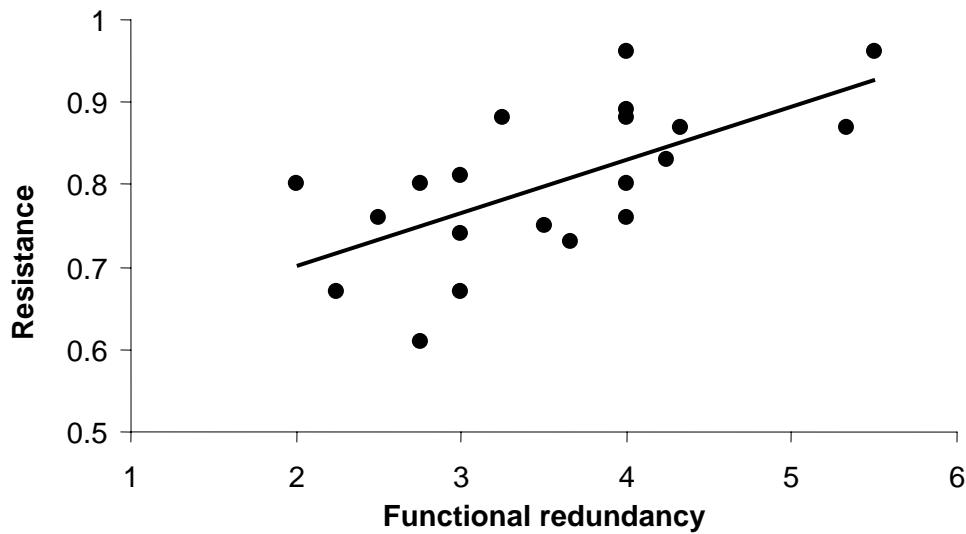


Figure 2. Relation of functional redundancy (initial number of species per functional group) to resistance on composition change (Sorensen index between final and initial states based on presence and absence of species) due to cattle grazing. Species grouped into four functional groups.

DISCUSSION

Although a positive effect of species richness to stability (resistance and resilience) of grasslands is suggested by the insurance hypothesis (Yachi & Loreau 1999) and some field experiments (Tilman & Downing 1994, Tilman et al. 2006), an inverse relationship has been also demonstrated (Pfisterer and Schimd 2002). Our results do not support this hypothesis, species richness had no effect on resistance of plant communities to cattle grazing. We suggest though, functional redundancy (here evaluated as number of species per functional group), better than species richness *per se* affects community stability.

Although interpretation on functional redundancy responses would depend on how species are grouped into functional groups (Gitay 1996) and on response variables considered (Duffy 2001), our results confirm the functional redundancy hypothesis for resistance of community composition to cattle grazing. Thus, functional redundancy should be regarded as an important natural property of communities to

resist disturbances. As greater functional redundancy levels are expected in richer communities (Hooper et al. 2005) a positive relation of species richness and resistance or resilience may also be found as an indirect relation. Management practices on pastures should consider functional redundancy levels to maintain biodiversity and sustainability.

ACKNOWLEDGEMENTS

Thanks to Adriano Mello for contributions on statistics. EMBRAPA financially supported project costs and Fernando Joner was fully supported by CAPES.

CITED LITERATURE

- BASKIN, Y. Ecosystem function of biodiversity. **BioScience**, n. 44, p. 657-660, 1994.
- BOWMAN, D. Cry shame on all humanity. **New Scientist**, n.144 p. 59, 1994.
- COWLING, R.M., MUSTART, PJ. LAURIE, H. AND RICHARDS, M.B. Species diversity; functional diversity and functional redundancy in fynbos communities. **South African Journal of Science**, n. 90, p. 333-337, 1994.
- DÍAZ, S., CABIDO, M. Vive la différence: plant functional diversity matters to ecosystem processes. **Trends in Ecology and Evolution**, n. 11, p. 646-655, 2001.
- DUFFY, J. E., MACDONALD, K.S., RHODE, J.M. PARKER, J.D. Grazer diversity, functional redundancy, and productivity in seagrass beds: an experimental test. **Ecology**, n. 82, p. 2417-2434, 2001.
- ELTON, C.S. **The reasons for conservation**. The Ecology of Invasions by Animals and Plants. ELTON, C.S. (ed.) Methuen, London p. 143-153, 1958.
- FIDELIS, A., OVERBECK, G., PILLAR, V.P. & PFADENHAUER, J. Effects of disturbance on population biology of the rosette species *Eryngium horridum* Malme in grasslands in southern Brazil. **Plant Ecology**, n. 195, p. 55-67, 2008.
- FONSECA, C.R.; GANADE, G. Functional redundancy, random extinctions and the stability of ecosystems. **Journal of Ecology**, n. 89, p. 118-125, 2001.
- FIDELIS, A., OVERBECK, G., PILLAR, V.P. & PFADENHAUER, J. Effects of disturbance on population biology of the rosette species *Eryngium horridum* Malme in grasslands in southern Brazil. **Plant Ecology**, n. 195 p. 55-67, 2008.
- GITAY, H. J., WILSON, J. B. LEE, W. G. Species Redundancy: A Redundant Concept? **Journal of Ecology**, n. 84, p. 121-124, 1996.
- HOOPER, D. U., CHAPIN III, F. S., EWEL, J. J., HECTOR, A., INCHAUSTI, P., LAVOREL, S., LAWTON, J. H., LODGE, D. M., LOREAU, M., NAEEM, S. SHMID, B. SETÄLÄ, SYMSTAD, A. J., VANDERMEER, J. AND WARDLE, D. A. Effects of Biodiversity on Ecosystem Functioning: A Consensus of Current Knowledge. **Ecological Monographs**, n. 75, p. 3-35, 2005.
- KENNEDY, A.C. AND SMITH, K.L. Soil microbial diversity and the sustainability of agricultural soils. **Plant and Soil**, n. 170, p. 75-86, 1995.
- LAWTON, J.H.; BROWN, V.K. Redundancy in ecosystems. In: SCHELZE, E.D.; MOONEY, H.A. (eds) **Biodiversity and ecosystem function**, Springer, Berlin Heidelberg, New Yourk, p. 255-270, 1993.
- MACARTHUR, R.H. Fluctuations of animal populations and a measure of community stability. **Ecology**, n. 36, p. 533-536, 1955.
- MAY, R.M. Will a large complex system be stable? **Nature**, n. 238, p. 413-414, 1972.
- NABINGER, C.; MORAES, A.; MARACHIN, G.E. Campos in Southern Brazil. In: LEMAIRE, G., HODGSON, J., MORAES, A., NABINGER, C., CARVALHO, P.C.F. (Eds.), **Grassland Ecophysiology and Grazing Ecology**. CAB International, pp. 355-376. 2000.
- NAEEM, S. Species redundancy and ecosystem reliability. **Conservation Biology**, n.12, p. 39-45, 1998.
- OVERBECK, G.E., MÜLLER, S.C., FIDELIS, A., PFADENHAUER, J., PILLAR, V.P., BLANCO, C.C., BOLDRINI, I.I., BOTH, R. & FORNECK, E.D. Brazil's neglected

- biome: The south Brazilian Campos. **Perspectives in Plant Ecology Evolution and Sistematics**, n. 9, p.101-116, 2007.
- PALMER, M.; WHITE, P. S. On the existence of ecological communities. **Journal of Vegetation Science**, n. 5, p. 279-282, 1994.
- PFISTERER, A.B.; SCHMID, B. Diversity-dependent production can decrease the stability of ecosystem functioning. **Nature**, n. 416, p. 84-86, 2002.
- PIMM, S.L. **The balance of nature: ecological issues in the conservation of species and communites**. University of Chicago Press, Chicago and London, 1991.
- ROSENFELD, J.S. Functional redundancy in ecology and conservation. **Oikos**, p. 98, p.156-162, 2002.
- SHULZE, E. D., AND MOONEY, H. A. (Ed.) **Biodiversity and Ecosystem Function**. Springer-Verlag, Berlin, Germany, 1993.
- TILMAN, D.; DOWNING, J.A. Biodiversity and stability in grasslands. **Nature**, n. 367, p. 363-365, 1994.
- WALKER, H.W. Biodiversity and Ecological Redundancy. **Conservation Biology**, n. 6, p. 18-23, 1992.
- _____. Conserving biological diversity through ecosystem resilience. **Conservation Biology**, n.9,p.747-752, 1995.
- YACHI, S., LOREAU, M. Biodiversity productivity in a fluctuating environment: the insurance hypothesis. **Proceedings of the National Academy of Sciences**, USA, n.96, p.1463-1468, 1999.

Redundância funcional e suas limitações e implicações para a conservação dos campos e práticas de manejo - Considerações finais

De forma geral, redundância funcional é uma propriedade inerente de qualquer sistema no qual existam elementos estruturados em grupos ou classes de acordo com as funções ou processos que nele desempenham, sendo esta o excedente do número de elementos necessários para o funcionamento deste sistema. Estes elementos não devem ser entendidos como *dispensáveis*, pois são potencialmente importantes para a manutenção do sistema quando for abalado ou quando houver perda de elementos. Esta propriedade pode ser percebida em sistemas de diferentes áreas do conhecimento, a exemplo de engenharia, genética, informática e ecologia.

Em ecologia a redundância funcional pode ser definida como: *a quantidade ou amplitude de elementos (espécies ou atributos funcionais) que excedem a quantidade ou amplitude necessárias para garantir o funcionamento do ecossistema, assegurando sua confiabilidade quando for perturbado*. Entretanto, a interpretação da redundância funcional de um ecossistema deve se limitar aos processos mensurados. Ou seja, não se pode generalizar a redundância das espécies mensuradas para um determinado processo para todas as funções existentes no ecossistema. Além disso, a interpretação da redundância funcional é dependente da forma como as espécies foram agrupadas em grupos funcionais, as quais muitas vezes são classificações subjetivas. Os grupos funcionais, é claro, devem refletir as funções ou processos a serem avaliados. Ainda assim, redundância funcional é uma

propriedade inerente destes sistemas que pode ser utilizada como uma ferramenta para avaliar quão robustos são os ecossistemas frente às perturbações.

Encontramos evidências de redundância funcional para as plantas dos ecossistemas campestres, classificando as espécies em graminóides e herbáceas (“*graminoids and forbs*”), pois a remoção de uma espécie de cada grupo funcional causou menor impacto na composição das espécies que a remoção de duas espécies do mesmo grupo funcional. Para a biomassa aérea, entretanto, não se pode concluir a respeito da existência de redundância entre as espécies. As espécies de um grupo funcional, principalmente dentre as herbáceas não-graminóides, tendem a compensar a perda de espécies do mesmo grupo. Esta compensação pode se dar devido à maior competição entre as espécies do mesmo grupo funcional, principalmente para as herbáceas não-graminóides.

Em ecossistemas campestres a redundância funcional aumenta a resistência das comunidades ao distúrbio causado pelo pastejo, ou seja, comunidades com maior redundância funcional (número de espécies por grupo funcional) têm uma menor mudança em sua composição qualitativa de espécies quando pastejadas.

O dinamismo da fisionomia e estrutura é uma característica importante dos campos sulinos que torna difícil a avaliação de sua estabilidade. Não se pode definir com clareza um estado estável para este sistema. Quando pastejados adequadamente os campos apresentam em sua estrutura dois estratos bem definidos (Overbeck et al. 2007): um estrato inferior composto por gramíneas estoloníferas como *Paspalum notatum* e *Axonopus affinis* e herbáceas não-graminóides *Dichondra sericea*, principalmente rosetadas (ou rosuladas) como *Eryngium ciliatum* e *Ruellia morongii* e um estrato superior composto por graminóides cespitosas mais altas como *Andropogon lateralis* e *Aristida spp.*

O pastejo excessivo, além de eliminar o estrato superior, tende a eliminar as espécies graminóides do estrato inferior deixando apenas espécies herbáceas não-graminóides de baixo valor forrageiro o que resulta numa menor cobertura do solo e riscos de erosão (Nabinger et al. 2000, Overbeck et al. 2007). Isto é, a atividade seletiva do gado quando a carga animal é muito elevada, reduz a redundância funcional de graminóides. Entretanto, quando o campo é completamente excluído de pastejo, o estrato inferior tende a desaparecer com o predomínio de touceiras de gramíneas (Boldrini e Eggers 1996, Quadros e Pillar 2001, Rodríguez et al. 2003).

Pastagens em áreas com maiores níveis de redundância funcional são mais resistentes ao pastejo e áreas de campo dentro de unidades de conservação deveriam ser manejadas de forma adequada, permitindo uma maior diversidade e níveis mais altos de redundância funcional. Entretanto, novos estudos são necessários para avaliar a importância da redundância funcional em experimentos de longa duração.

REFERÊNCIAS BIBLIOGRÁFICAS

- AARSEN, L.W.; EPP, G.A. Neighbour manipulations in natural vegetation: a review. *Journal of Vegetation Science*, n. 1, p. 13-30, 1990.
- BLANCO, C. C. **Reconstrução da dinâmica de curta duração em vegetação campestre sob pastejo, com base em tipos funcionais.** 2004. 96 f. Dissertação (Mestrado) - Universidade Federal do Rio Grande do Sul, Programa de Pós-graduação em ecologia, Porto Alegre, 2004.
- BEHLING, H. Late quaternary vegetational and climatic changes in Brazil. *Rev. Palobotat. Palynol.* n. 99, p.143-156, 1998.
- BEHLING, H. South and southeast Brazilian grasslands durin Late Quaternary times: a synthesis. *Paleogeogr. Paleoclim. Paleoecol.* n. 177, p. 19-27, 2002.
- BEHLING, H., PILLAR, V.P., MÜLLER, S.C., OVERBECK, G.E. Late-Holocene fire history in a forest-grassland mosaic in southern Brazil: Implications for conservation. *Applied Vegetation Science*. n. 10, p. 81-90, 2007.
- BOLDRINI, I. I. Dinâmica de vegetação de uma pastagem natural sob diferentes níveis de oferta de forragem e tipos de solos, Depressão Central, RS. 1993. 262 f. Tese (Doutorado) – Universidade Federal do Rio Grande do Sul, Programa de Pós-graduação em Agronomia, Porto Alegre, 1993.
- BOLDRINI, I., EGGLERS, L. vegetação campestre do sul do Brasil: dinâmica de espécies a exclusão do gado. *Acta Bot. Bras.* n. 10, p. 37-50, 1996.
- CABRERA, A.L., WILLINK, A. **Biogeografia da America Latina.** Washington: OEA, 1980.117 p.
- CHAPIN, F.S.; SALA, O.E.; BURKE, I.C.; GRIME, J.P.; HOOPER D.U.; LAUENROTH, W.K.; LOMBARD, A.; MOONEY, H. A.; MOISER, A.R.; NAEEM, S.; PACALA, S.W.; ROY, J.; STEFFEN, W.L.; TILMAN, D. Ecosystem consequences of changing biodiversity. *Bioscience*, n. 48, p. 45-52, 1998.
- CHAPIN, F.S.; WALKER B.H.; HOBBS R.J.; HOOPER D.U.; LAWTON J.H.; SALA O.E.; TILMAN D. Biotic control over the functioning of ecosystems. *Science*, n. 277, p. 500-503, 1997.
- CLEMENTS, F.E., WEAVER, J. E., HANSON, H.C. **Plant competition. An analysis of community functions.** Carnegie Insituition, Wachington, 1929.
- COWGHENOUR, M.B. Spatial components of plant-herbivore interactions in pastoral, ranching and native ungulate ecosystems. *Journal of Range Management*. n. 44, p. 530-541, 1991.
- DARWIN, C. **On the origin of species**, Murray, London. 1859.
- DIAMOND, J.M. **Assembly of species communities.** Ecology and evolution of communities. DIAMOND, J.M., CODY, M.L., (ed.), pp 342-44. Harvard University Press, Cambridge, MA, 1975.
- DÍAZ, S.; CABIDO, M. Plant functional types and ecosystem function in relation to global change. *Journal of Vegetation Science*, n.8, p. 463-474, 1997.
- DÍAZ, S.; SYMSTAD, A.J.; CHAPIN III, F. S.; WARDLE, D. A.; HUENNEKE, L.F. Functional diversity revealed by removal experiments. *Trends in Ecology and Evolution*, n. 18, p. 140-146, 2003.
- DURIETZ, G.E. Fife-forms of terrestrial flowering plants. *Acta Phytoegor. Suec.* n. 3, p. 1-95. 1931.
- EDWARDS, P.J.; ABIVARDI, C. The value of biodiversity: where ecology and economy blend. *Biological Conservation*, n 83, p. 239-246, 1998.

- ELTON, C.S. **The reasons for conservation.** The Ecology of Invasions by Animals and Plants. ELTON, C.S. (ed.) Methuen, London p. 143-153, 1958.
- FINLAY, B.J.; MABERLY, S.C.; COOPER, J.I. Microbial diversity and ecosystem function. *Oikos*, n 80, p. 209-213, 1997.
- KEDDY, P.A. Assembly and response rules: two goals for predictive community ecology. *Journal of Vegetation Science*, n. 3 p. 157-164, 1992.
- LAVOREL, S.; GARNIER, E. Predicting changes in community composition and ecosystem functioning from plant traits: revisiting the Holy Grail. *Funcional Ecología*, n. 16, p. 545-556, 2002.
- LAWTON, J.H.; BROWN, V.K. Redundancy in ecosystems. In: SCHELZE, E.D.; MOONEY, H.A. (eds) **Biodiversity and ecosystem function**, Springer, Berlin Heidelberg, New Yourk, p. 255-270, 1993.
- LEDRU, M.P., SALGADO-LABOURIAU, M.L., LORCSHETTER, M.L. Vegetation dynamics in southern and central Brazil during the last 10,000 yr. *B.P Rev. Palynol.* n. 99, p. 131-142, 1998.
- LEHMAN, C. L.; TILMAN, D. Biodiversity, stability, and productivity in competitive communities. *American Naturalist*, n. 156, p. 534-552, 2000.
- MACARTHUR, R.H. Fluctuations of animal populations and a measure of community stability. *Ecology*, n. 36, p. 533-536, 1955.
- MAY, R.M. Will a large complex system be stable? *Nature*, n. 238, p. 413-414, 1972.
- MCGRADY-STEEED, J.; HARRIS, P. M.; MORIN, P.J. Biodiversity regulates ecosystem predictability. *Nature*, n. 390, p. 162-165, 1997.
- MÜLLER, S.C., OVERBECK, G.E., PFADENHAUER, J., PILLAR, V.D. Plant functional types of woody species related to fire disturbance in forest-grassland ecotone. *Plant ecology*, n. 189, p. 1-14, 2006.
- NABINGER, C.; MORAES, A.; MARACHIN, G.E. Campos in Southern Brazil. In: LEMAIRE, G., HODGSON, J., MORAES, A., NABINGER, C., CARVALHO, P.C.F. (Eds.), *Grassland Ecophysiology and Grazing Ecology*. CAB International, pp. 355-376. 2000.
- OVERBECK, G.E., MÜLLER, S.C., FIDELIS, A., PFADENHAUER, J., PILLAR, V.P., BLANCO, C.C., BOLDRINI, I.I., BOTH, R. & FORNECK, E.D. Brazil's neglected biome: The south Brazilian Campos. *Perspectives in Plant Ecology Evolution and Sistematics*, n. 9, p.101-116, 2007.
- PFISTERER, A.B.; SCHMID, B. Diversity-dependent production can decrease the stability of ecosystem functioning. *Nature*, n. 416, p. 84-86, 2002.
- PILLAR, V.D., QUADROS, F.L.F. Grassland-forest boundaries in southern Brazil. *Coenoses*, n. 12, p. 119-126, 1997.
- PILLAR, V. D.; SOSINSKI, E. E.. An improved method for searching plant functional types by numerical analysis. *Journal of Vegetation Science*, n.14, p. 323-332, 2003.
- RAMBO, B. **A fisionomia do Rio Grande do Sul.** Porto Alegre, Selbach. p. 473, 1956.
- RODRÍGUEZ, C. LEONI, E., LEZAMA, F. ALTERSOR, A. Temporal trends in species composition and plant traits in natural grasslands of Uruguay, *Journal of Vegetation Science*, n. 14, p. 433-440, 2003.
- RAUNKIER, C. **The statistics of life-forms of plants and statiscal plant geography;** the collected papers of C. Raunkiaer, pp. 111-147. Clarendon Press, Oxford, UK, 1934.

- SENFT, R.L., COUGHENOUR, M.B., BAILEY, D.W., TITTENHOUSE, L.R., SALA, O.E., SWIFT, D.M. Large herbivore foraging and ecological hierarchies. *Bioscience* n. 37, p. 789-799, 1987.
- SOSINSKI, E.E. *Modelos de Simulação Espacial de Efeitos de Pastejo em Vegetação Campestre*. 2005. 125 f. Tese (Doutorado) – Universidade Federal do Rio Grande do Sul, Programa de Pós-graduação em ecologia, Porto Alegre, 2005.
- TRINDADE, J.P.P. Processos de degradação e regeneração da vegetação campestre do entorno de areais do sudeste do Rio Grande do Sul. Tese de Doutorado, Departamento de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil, 2003.
- TILMAN, D.; DOWNING, J.A. Biodiversity and stability in grasslands. *Nature* n. 367, p. 363-365, 1994.
- TILMAN, D.; WEDIN, D.; KNOPS, J. Productivity and sustainability influenced by biodiversity in grassland ecosystems. *Nature*, n. 379, p. 718-720, 1996.
- TILMAN, D. Biodiversity and ecosystem functioning, In: DAILY G.C. (ed) **Nature's services: social dependency on natural ecosystems**, Island, Washington, p.93-112, 1997.
- TILMAN, D.; REICH, P.; PHILLIPS, H.; MENTON, M.; PATEL, A.; VOS, E.; PETERSON, D.; KNOPS, J. Fires suppression and ecosystem carbon storage. *Ecology*, n. 81, p. 2680-2685, 2000.
- WALKER, H.W. Biodiversity and Ecological Redundancy. *Conservation Biology*, n. 6, p. 18-23, 1992.
- WARDLE, D.A.; ZACKRISSON, O.; HORNBERG, G.; GALLET, C. The influence of island area on ecosystem properties. *Science*, n. 277, p. 1296-1299, 1997.
- WARMING, E.: Plantesanfund; Grundtraek af den okologiske plantgeografi. Philipsens, Kobenhavn. Traduzido para o Inglês como: **Oecology of Plants: an introduction to the study of plant communities**. Clarendon Press, Oxford, UK, 1895.
- WILSON, J.B.; TOXBURGH, S.H. Ademonstration of guild-based assembly rules for a plant community, and determination of intrinsic guilds. *Oikos*, n. 69, p. 267-276, 1994.

APÊNDICES

Apêndice 1. List of species found in the experiment classified into two functional groups (Graminoids and Forbs).

Species	Functional group	Family
<i>Abildgaardia ovata</i> (Burm.f.) Kral	Graminoid	Cyperaceae
<i>Aeschynomene falcata</i> Desv.	Forb	Leguminosae
<i>Andropogon lateralis</i> Nees	Graminoid	Poaceae
<i>Andropogon sellianus</i> Hack.	Graminoid	Poaceae
<i>Aristida laevis</i> Kunth	Graminoid	Poaceae
<i>Aristida venustula</i> Arechav.	Graminoid	Poaceae
<i>Aspilia montevidensis</i> Kuntze	Forb	Asteraceae
<i>Axonopus affinis</i> Chase	Graminoid	Poaceae
<i>Baccharis trimera</i> DC.	Forb	Asteraceae
<i>Borreria brachystemonoides</i> Cham. & Schltdl.	Forb	Rubiaceae
<i>Borreria eryngioides</i> Cham. & Schltdl.	Forb	Rubiaceae
<i>Borreria verticillata</i> G.Mey.	Forb	Rubiaceae
<i>Briza subaristata</i> Lam.	Graminoid	Poaceae
<i>Bulbostylis capillaris</i> Nees	Graminoid	Cyperaceae
<i>Centella asiatica</i> Urban	Forb	Apiaceae
<i>Chaptalia runcinata</i> H.B. & K.	Forb	Asteraceae
<i>Chevreulia acuminata</i> Less.	Forb	Asteraceae
<i>Chevreulia sarmentosa</i> S.F.Blake	Forb	Asteraceae
<i>Coelorachis selliana</i> (Hackel) A.Camus	Graminoid	Poaceae
<i>Cliococca selaginoides</i> (Lam.) C.M.Rogers & Mildner	Forb	Linaceae
<i>Clitoria nana</i> Benth.	Forb	Leguminosae
<i>Conyza primulifolia</i> (Lam.) Cuatrec. & Lourteig	Forb	Asteraceae
<i>Conyza bonariensis</i> (L.) Cronquist	Forb	Asteraceae
<i>Crotalaria tweediana</i> Benth.	Forb	Leguminosae
<i>Cuphea glutinosa</i> Cham. & Schltdl.	Forb	Lythraceae
<i>Cynodon</i> sp.	Graminoid	Poaceae
other Cyperaceae	Graminoid	Cyperaceae
<i>Danthonia secundiflora</i> J.Presl & C.Presl	Graminoid	Poaceae
<i>Desmanthus tatuhyensis</i> Hoehne	Forb	Leguminosae
<i>Desmodium incanum</i> DC.	Forb	Leguminosae
<i>Dichondra sericea</i> Sw.	Forb	Convolvulaceae
<i>Diodia apiculata</i> Schum.	Forb	Rubiaceae
<i>Elyonurus</i> sp.	Graminoid	Poaceae
<i>Eragrostis neesii</i> Trin.	Graminoid	Poaceae
<i>Eragrostis plana</i> Nees	Graminoid	Poaceae
<i>Eryngium ciliatum</i> Cham. & Schltdl.	Forb	Apiaceae
<i>Eryngium horridum</i> Malme	Forb	Apiaceae
<i>Euphorbia selloi</i> Boiss.	Forb	Euphorbiaceae
<i>Evolvulus sericeus</i> Sw.	Forb	Convolvulaceae
<i>Facelis retusa</i> Sch.Bip.	Forb	Asteraceae
<i>Fimbristylis diphylla</i> Vahl	Graminoid	Cyperaceae
<i>Fimbristylis</i> sp.	Graminoid	Cyperaceae
<i>Galactia marginalis</i> Benth.	Forb	Leguminosae
<i>Galianthe fastigiata</i> Griseb	Forb	Leguminosae
<i>Gamochaeta americana</i> Wedd.	Forb	Asteraceae

Apêndice 1. Contin.

Species	Functional group	Family
<i>Glandularia megapotamica</i> cabrera & dawson	Forb	Verbenaceae
<i>Gratiola peruviana</i> Walter	Forb	Scrophulariaceae
<i>Helianthemum brasiliense</i> Pers.	Forb	Cistaceae
<i>Hydrocotyle exigua</i> Malme	Forb	Apiaceae
<i>Hybanthus bicolor</i> Taub.	Forb	Violaceae
indeterminate Forb 1	Forb	
indeterminate Forb 2	Forb	
indeterminate Forb 3	Forb	
indeterminate Forb 4	Forb	
indeterminate Forb 5	Forb	
indeterminate Gramineae	Graminoid	Poaceae
<i>Krapovickasia macrodon</i> (DC.) Fryxell	Forb	Malvaceae
<i>Kyllinga vaginata</i> Rchb.f. ex Kunth	Graminoid	Cyperaceae
<i>Mecardonia tenella</i> (Cham. & Schlechtend.) Pennell.	Forb	Scrophulariaceae
<i>Noticastrum decumbens</i> (Baker) Cuatrec	Forb	Asteraceae
<i>Oxalis</i> sp.	Forb	Oxalidaceae
<i>Oxalis conorrhiza</i> Jacq.	Forb	Oxalidaceae
<i>Oxalis eriocarpa</i> DC.	Forb	Oxalidaceae
<i>Panicum bergi</i> Arechav.	Graminoid	Poaceae
<i>Dichanthelium sabulorum</i> (Lamarck) Gould & C.A.Clark	Graminoid	Poaceae
<i>Paspalum maculosum</i> Trin.	Graminoid	Poaceae
<i>Paspalum notatum</i> Fluegge	Graminoid	Poaceae
<i>Paspalum paucifolium</i> Swallen	Graminoid	Poaceae
<i>Paspalum plicatulum</i> Michx.	Graminoid	Poaceae
<i>Paspalum pumilum</i> Nees	Graminoid	Poaceae
<i>Peltodon longipes</i> A.St.-Hil. ex Benth.	Forb	Lamiaceae
<i>Pfaffia tuberosa</i> (Moq. ex DC.) Hicken	Forb	Amaranthaceae
<i>Piptochaetium montevidense</i> Parodi	Graminoid	Poaceae
<i>Piptochaetium stipoides</i> Hackel ex Arechav.	Graminoid	Poaceae
<i>Piriqueta selloi</i> Urban	Forb	Turneraceae
<i>Plantago myosuros</i> Lam.	Forb	Plantaginaceae
<i>Podocoma hirsuta</i> Baker	Forb	Asteraceae
<i>Polygala linooides</i> Poir.	Forb	Polygalaceae
<i>Polygala pumila</i> Norlind	Forb	Polygalaceae
<i>Polygala adenophylla</i> A.W.Benn.	Forb	Polygalaceae
<i>Psidium luridum</i> (Spreng.) Burret	Forb	Myrtaceae
<i>Pteurocaulon</i> sp.	Forb	Asteraceae
<i>Relbunium richardianum</i> Hicken	Forb	Rubiaceae
<i>Rhynchospora tenuis</i> Link	Graminoid	Cyperaceae
<i>Richardia brasiliensis</i> Gomez	Forb	Rubiaceae
<i>Richardia grandiflora</i> Britton	Forb	Rubiaceae
<i>Richardia humistrata</i> Steud.	Forb	Rubiaceae
<i>Richardia stellaris</i> Steud.	Forb	Rubiaceae
<i>Ruellia morongii</i> Britton	Forb	Acanthaceae
<i>Sacciolepis vilvooides</i> Chase	Graminoid	Poaceae

Apêndice 1. Contin.

Species	Functional group	Family
<i>Schizachyrium spicatum</i> (Spreng.) Herter	Graminoid	Poaceae
<i>Scleria distans</i> Poir.	Graminoid	Cyperaceae
<i>Setaria parviflora</i> (Poir.) Kerguélen	Graminoid	Poaceae
<i>Sida rhombifolia</i> L.	Forb	Malvaceae
<i>Sisyrinchium</i> sp.	Forb	Iridaceae
<i>Sporobolus indicus</i> R.Br.	Graminoid	Poaceae
<i>Stellaria media</i> (L.) Vill.	Forb	Caryophyllaceae
<i>Stevia aristata</i> D.Don ex Hook. & Arn.	Forb	Asteraceae
<i>Stylosanthes leiocarpa</i> Vog.	Forb	Leguminosae
<i>Stylosanthes montevidensis</i> Vog.	Forb	Leguminosae
<i>Tibouchina gracilis</i> Cogn.	Forb	Melastomataceae
<i>Turnera</i> sp.	Forb	Turneraceae
<i>Vernonia flexuosa</i> Sims	Forb	Asteraceae
<i>Vernonia megapotamica</i> Spreng.	Forb	Asteraceae
<i>Vernonia nudiflora</i> Less.	Forb	Asteraceae
<i>Vernonia sellowii</i> Less.	Forb	Asteraceae
<i>Wahlenbergia linarioides</i> A.DC.	Forb	Campanulaceae
<i>Zornia reticulata</i> Sm.	Forb	Leguminosae

Apêndice 2. Levantamento da composição e proporção da cobertura de espécies do experimento de remoção (sem os valores de rebrote das plantas removidas).

Levantamento	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2				
Parcela	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	32	33	35	36	38	39	40
Tratamento	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
Quadro	1C	2D	3D	4A	5C	6C	7B	8A	9C	10C	11C	12B	13A	14D	15D	16B	17A	18B	19D	20D	21D	22B	23A	24B	25A	26B	27B	29D	30C	32C	33C	35D	36C	38A	39C	40B	
Solo nu	40	30	20	30	20	50	50	5	50	40	60	50	40	60	60	50	60	40	20	5	50	50	10	20	40	50	70	30	30	20	10	30	20	50	30	10	
Abildgaardia ovata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
Aeschynomene falcata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
Andropogon lateralis	0	0	0	5	0	0	3	0	10	20	0	10	0	0	5	0	0	0	0	0	0	10	0	0	5	5	0	5	10	0	0	0	0	0			
Andropogon seloano	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	5	0	20	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0			
Aristida levis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0				
Aristida venustula	0	0	10	0	0	0	0	5	0	0	0	0	10	0	0	0	5	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0			
Aspilia montevidense	0	0	0	5	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	5	0	0	0	2	0	0			
Axonopus affinis	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	10	0	5	0	0	0	0	10	0	0	0	0	5	0	0	0	0	5	0		
Bacharis trimera	5	5	0	3	0	0	0	0	5	0	10	1	0	5	2	0	0	10	0	0	0	0	1	0	0	0	10	2	40	0	0	0	1	0	0		
Borreria brachystemioides	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Borreria eringooides	0	0	0	0	0	0	2	0	2	0	0	0	0	1	0	0	0	2	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0			
Borreria verticilata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Brisa subaristata	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Bulbostylis capilaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	10	0	0	0	0	5	0	0	0	5	0	0		
Centella asiatica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0			
Chaptalia runcinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		
Chevreulia acuminata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0			
Chevreulia sarmentosa	0	0	0	0	1	0	0	5	0	0	0	0	1	0	0	0	4	0	0	10	0	1	5	0	0	0	0	0	0	0	0	0	10	0	5		
Choelorachis seloana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0		
Cliococa selaginoides	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Clitoria nana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	10	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0		
Conisa primulifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Coniza bonariensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Crotalaria tueidiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Cuffea glutinosa	0	5	0	0	4	1	0	1	2	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	3	2	1	1	0			
Cynodon sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Cyperaceae	5	0	0	0	0	0	5	10	1	10	0	0	0	2	5	0	5	0	0	5	0	0	10	5	5	0	0	0	0	0	0	0	0	0	0		
Danthonia secundiflora	0	10	0	0	0	5	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Desmanthus	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Desmodium incanum	0	0	5	0	3	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	10	0	5			
Dicondra sericia	10	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	10	0	0	0	0	0	0	0	0	
Drodia apiculata	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		

Levantamento	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2				
Parcela	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	29	30	32	33	35	36	38	39	40
Tratamento	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3			
Quadro	1B	2A	3B	4B	5B	6A	7C	8C	9D	10B	11A	12D	13B	14C	15B	16A	17D	18D	19C	20B	21C	22A	23B	24C	25B	26C	27A	29B	30A	32D	33D	35A	36A	38B	39A	40C
Solo nu	25	40	40	30	20	20	50	20	50	70	30	30	40	30	70	60	30	20	60	5	30	40	30	30	20	60	40	5	30	20	5	10	30	30	70	10
Abildgaardia ovata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Aeschynomene falcata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Andropogon lateralis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Andropogon seloano	0	0	0	5	0	0	0	10	0	0	0	20	0	0	0	0	0	20	0	5	0	0	10	0	0	10	0	0	0	0	0	0	0			
Aristida levis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	4	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0			
Aristida venustula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Aspilia montevidense	10	10	0	0	0	0	0	0	0	0	10	0	0	0	0	0	2	0	0	0	0	0	0	0	10	5	0	0	0	0	0	0	5	0		
Axonopus affinis	10	5	0	0	0	0	0	0	5	0	5	0	0	0	4	0	0	0	0	5	3	0	0	0	0	0	0	0	0	0	0	0	10	0		
Bacharis trimera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	5	0	0	0	20	0	0	0	0	0	0	0	0	0	5	0			
Borreria brachystemioides	0	3	0	0	0	0	0	0	4	0	1	1	1	0	2	1	0	0	0	2	0	1	1	0	1	10	5	5	0	0	1	4	0	0		
Borreria eriogoides	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Borreria verticillata	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Brisa subaristata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0			
Bulbostylis capilaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Centella asiatica	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Chaptalia runcinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Chevreulia acuminata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Chevreulia sarmentosa	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Chaelorachis seloana	2	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5	0	0	0	0	0	0	5	1	0	5	0	0	0	0	0	10	0	0		
Cliococa selaginoides	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Clitoria nana	0	0	4	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Conisa primulifolia	0	0	0	0	0	0	0	0	0	1	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0		
Coniza bonariensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Crotalaria tuediana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
Cuffea glutinosa	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Cynodon sp	2	1	2	0	0	0	1	0	2	0	0	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0		
Cyperaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Danthonia secundiflora	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	5	5	0	0	0	5	0	0	0	0	0	0	0	0		
Desmanthus	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Desmodium incanum	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Dicondra sericia	0	0	4	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5		
Drodia apiculata	0	0	0	5	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	

Levantamento	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3			
Parcela	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	29	30	32	33	35	36	38	39	40		
Tratamento	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
Quadro	1C	2D	3D	4A	5C	6C	7B	8A	9C	10C	11C	12B	13A	14D	15D	16B	17A	18B	19D	20D	21D	22B	23A	24B	25A	26B	27B	29D	30C	32C	33C	35D	36C	38A	39C	40B		
Solo nu	5	10	10	5	10	20	30	5	20	5	30	10	20	50	0	5	40	20	20	0	20	20	0	10	30	20	50	10	5	10	0	10	5	10	10	0		
Abildgaargia ovata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Aeschynomene falcata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Andropogon lateralis	0	0	0	30	5	0	20	0	10	20	0	20	0	0	0	0	0	0	0	0	0	20	10	0	10	10	0	10	0	0	0	0	0	0	0			
Andropogon seloano	0	5	0	0	0	5	0	5	0	10	0	0	0	0	0	0	10	5	10	20	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0			
Aristida levis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Aristida venustula	0	0	10	0	5	0	0	5	0	0	0	0	5	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	
Aspilia montevidense	0	5	1	10	0	0	0	2	20	0	0	0	0	2	0	5	0	0	0	0	0	10	0	0	0	0	0	0	2	10	0	0	0	10	0	10	0	
Axonopus affinis	0	0	5	0	0	0	0	30	0	5	0	20	0	0	20	0	10	10	20	20	20	0	0	20	0	0	0	10	0	0	0	0	0	0	10	0	0	
Bacharis trimera	20	5	0	1	0	0	0	0	5	0	20	0	0	20	10	5	0	5	0	0	2	0	0	0	0	20	0	40	0	0	0	4	0	0	10	0		
Borreria brachystemoides	0	0	0	0	0	0	0	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Borreria eringoides	5	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Borreria verticillata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Brisa subaristata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Bulbostylis capilaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Centella asiatica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4		
Chaptalia runcinata	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	20	5	5	0	0	0	0	3	0	0	0	0	0	0	0	3	0	
Chevreulia acuminata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	1	0		
Chevreulia sarmentosa	0	0	0	0	0	0	0	3	0	0	2	5	0	0	0	5	5	2	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	
Choelorachis seloana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Cliococa selaginoides	0	0	0	0	0	0	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Clitoria nana	0	0	0	0	5	0	0	0	0	0	0	0	0	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Conisa primulifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Coniza bonariensis	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Crotalaria tuediana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Cuffea glutinosa	0	0	0	0	0	2	3	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	2	1	0	
Cynodon sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Cyperaceae	5	0	10	5	0	5	0	0	5	5	5	0	0	3	5	0	10	0	5	5	5	0	0	0	10	10	0	0	0	0	5	0	0	10	0	0		
Danthonia secundiflora	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	
Desmanthus	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Desmodium incanum	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	5	0	0	5	0	0	10	0		
Dicondra sericia	0	0	0	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5	0	0	3	1	0	0		
Drodia apiculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Levantamento	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3			
Parcela	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	29	30	32	33	35	36	38	39	40		
Tratamento	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3			
Quadro	1B	2A	3B	4B	5B	6A	7C	8C	9D	10B	11A	12D	13B	14C	15B	16A	17D	18D	19C	20B	21C	22A	23B	24C	25B	26C	27A	29B	30A	32D	33D	35A	36A	38B	39A	40C		
Solo nu	10	10	30	10	0	5	30	10	10	50	20	10	30	30	20	10	20	0	20	0	20	30	5	0	5	30	20	5	0	0	0	0	5	10	10	0		
Abildgaargia ovata	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Aeschynomene falcata	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Andropogon lateralis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Andropogon seloano	0	0	10	20	0	0	0	5	0	0	0	20	0	0	0	10	0	10	0	5	0	0	10	0	10	20	0	10	10	0	0	0	0	0	0			
Aristida levis	0	0	5	0	5	0	0	0	0	0	0	0	0	0	0	10	40	10	20	5	10	10	0	0	0	0	0	0	0	0	0	0	0	0				
Aristida venustula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Aspilia montevidense	10	20	5	0	0	0	0	5	0	0	5	0	0	0	0	5	0	0	0	0	5	0	0	0	10	5	0	0	0	0	0	0	0	0	10	0		
Axonopus affinis	10	0	0	10	0	0	4	0	5	20	0	0	20	0	10	0	0	0	0	10	3	0	10	0	0	0	0	0	0	0	0	0	0	20	0			
Bacharis trimera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	10	5	5	10	0	10	0	0	0	0	0	0	0	0	0	10	5	0	10	10	0	
Borreria brachystemioides	0	5	0	2	0	0	0	0	10	1	2	1	0	0	5	0	0	0	0	2	0	0	0	0	0	20	5	5	0	0	0	5	0	0	0	0		
Borreria eringooides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Borreria verticillata	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	
Brisa subaristata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Bulbostylis capilaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Centella asiatica	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Chaptalia runcinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Chevreulia acuminata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0		
Chevreulia sarmentosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0		
Choelorachis seloana	0	0	0	2	0	0	0	0	0	5	5	0	0	0	10	0	4	0	0	0	2	0	5	0	10	0	0	0	0	0	0	0	0	10	0	0		
Cliococa selaginoides	0	0	0	0	0	0	0	0	5	0	5	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Clitoria nana	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Conisa primulifolia	0	0	0	0	0	0	0	0	0	3	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0		
Coniza bonariensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Crotalaria tuediana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Cuffea glutinosa	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Cynodon sp	2	1	1	1	0	3	0	0	1	0	0	0	0	4	2	2	0	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0		
Cyperaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Danthonia secundiflora	0	5	0	0	5	5	5	0	0	0	0	0	0	0	0	0	10	5	5	10	5	5	0	0	10	0	5	0	5	0	10	0	0	5	0			
Desmanthus	0	0	10	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Desmodium incanum	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Dicondra sericia	0	0	10	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	
Drodia apiculata	5	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0

Levantamento	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3				
Parcela	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	29	30	32	33	35	36	38	39	40	
Tratamento	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4				
Quadro	1D	2C	3A	4D	5A	6D	7A	8B	9A	10D	11D	12A	13C	14B	15A	16C	17C	18C	19B	20C	21A	22C	23C	24A	25C	26A	27C	29A	30B	32B	33A	35B	36B	38C	39B	40A	
Solo nu	5	0	0	10	5	0	0	10	5	0	5	0	0	0	10	0	0	0	10	0	30	20	0	0	0	5	5	10	5	0	0	5	10	10	0		
Abildgaargia ovata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Aeschynomene falcata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Andropogon lateralis	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Andropogon seloano	0	0	5	30	0	5	20	0	20	20	5	30	5	30	0	0	0	10	5	10	5	0	20	20	0	0	60	10	0	0	30	0	0	0			
Aristida levis	0	5	0	0	0	0	0	10	0	0	0	0	0	0	0	10	0	10	0	10	0	0	0	5	0	0	0	0	0	0	0	0	0	0			
Aristida venustula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0			
Aspilia montevidense	5	5	20	0	5	0	0	5	10	5	0	0	0	5	0	0	5	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0		
Axonopus affinis	0	0	0	0	5	0	10	0	5	0	10	30	0	0	0	10	0	0	0	0	0	10	0	5	10	0	0	0	0	0	0	0	5	0	10	0	
Bacharis trimera	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	10	0	5	10	10	5	0	0	10	0	10	5	0	0	20	0	5	0	0		
Borreria brachystemioides	5	0	10	0	0	0	0	0	5	5	5	0	0	10	1	0	0	0	0	0	10	10	0	0	0	5	1	0	0	0	0	3	0	0	0		
Borreria eringioides	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Borreria verticillata	0	0	0	0	0	0	0	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0		
Brisa subaristata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Bulbostylis capilaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Centella asiatica	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	5	0	0	5	0	0	0	0	0	0	0	0		
Chaptalia runcinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Chevreulia acuminata	0	0	0	0	0	0	0	0	5	0	0	5	4	5	0	0	0	0	5	10	5	0	0	0	0	2	0	0	0	0	0	0	3	0	0	0	
Chevreulia sarmentosa	0	0	2	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	20	10	0		
Choelorachis seloana	0	0	10	0	0	0	0	5	0	0	0	0	0	0	0	10	10	1	0	0	0	10	0	0	0	0	0	0	0	0	0	0	10	0	0	5	
Cliococa selaginoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	5	0	0	0	
Clitoria nana	0	0	0	0	0	0	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Conisa primulifolia	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	
Coniza bonariensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Crotalaria tuediana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Cuffea glutinosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Cynodon sp	5	5	0	4	0	0	3	0	1	0	0	0	0	0	1	0	3	1	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	
Cyperaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Danthonia secundiflora	0	5	10	5	5	5	5	5	0	0	0	0	0	0	0	0	0	0	5	5	0	5	0	0	0	5	0	0	0	0	0	0	0	0	0	10	10
Desmanthus	0	0	5	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Desmodium incanum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Dicondra sericia	0	0	0	5	0	0	0	0	0	0	5	0	0	0	0	4	0	0	0	0	5	4	0	5	0	0	0	10	0	0	0	0	10	0	5		
Drodia apiculata	0	0	0	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	

