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Changes in plant community diversity and composition across an edge between Araucaria forest and pasture in South Brazil

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ABSTRACT – (Changes in plant community diversity and composition across an edge between Araucaria forest and pasture in South Brazil). This work investigated how richness, abundance, composition and structure of woody and herbaceous vegetation were altered by the proximity of an edge between Araucaria forest and pasture in South Brazil. Herbaceous and woody species including seedlings were surveyed in 42 plots of 5 × 5 m randomly placed at the following distances: 5 and 50 m from the edge into the pasture and 0, 25, 50, 100 and 250 m from the edge into the forest. There was a significant increase in vegetation cover, richness and abundance of woody species, woody seedlings and herbaceous plants at the edge (0 m). These variables, in general, decreased from 25 to 50 m from the edge into the forest in comparison to the forest interior. Few seedlings of woody plants were able to establish themselves in the pasture. There were continuous changes in species composition that occurred in the studied gradient due to the invasion of light-demanding species and the disappearance of some shade-tolerant species at the edge. In conclusion, the forest edge studied generated changes in the plant community that extended up to 50 m into the forest.

Key words - edge effects, herbaceous vegetation, seedling diversity, tree species composition, woody plants richness

RESUMO – (Mudanças na composição e diversidade de uma comunidade de plantas ao longo de uma borda entre floresta com araucária e pastagem no Sul do Brasil). Neste estudo investigamos como riqueza, abundância, composição e estrutura da vegetação lenhosa e herbácea foram alteradas pela proximidade de uma borda entre floresta com araucária e pastagem no sul do Brasil. Espécies lenhosas e herbáceas, incluindo plântulas, foram analisadas em 42 parcelas de 5 × 5 m dispostas aleatoriamente nas seguintes distâncias: 5 e 50 m da borda para dentro do campo e 0, 25, 50, 100 e 250 m da borda para dentro da floresta. Houve um aumento significativo na cobertura da vegetação, riqueza e abundância de espécies lenhosas, plântulas lenhosas e plantas herbáceas na borda (0 m). Essas variáveis, em geral, decresceram nas distâncias 25 a 50 m da borda para dentro da floresta em relação ao interior da mesma. Poucas plântulas lenhosas foram capazes de estabelecer-se no campo. Houve uma mudança contínua na composição de espécies que ocorreu no gradiente de borda devido à invasão de espécies heliófilas e o desaparecimento de alguma espécies tolerantes à sombra na borda. Concluímos que a comunidade de plantas encontra-se alterada na borda florestal estudada em uma extensão que vai até 50 m para dentro da floresta.

Palavras-chave - composição de espécies arbóreas, diversidade de plântulas, efeito de borda, riqueza de plantas lenhosas, vegetação herbácea

Introduction

The creation of an interface between forest and deforested areas can lead to sudden changes in the environmental conditions of these forests, here referred to as “edge effects” (Murcia 1995). These changes begin with the development of microclimatic gradients where the influence zone of the edge presents a greater exposure to winds, higher temperatures, lower humidity and higher sun radiation (Kapos 1989, Matlack 1993, Camargo & Kapos 1995, Kapos *et al.* 1997, Davies-Colley *et al.* 2000, Redding *et al.* 2003). These altered conditions can extend up to 100 m into the forest (Young & Mitchell 1994).

Such environmental changes associated with forest edges can negatively affect the plant community that survives in forest remnants (Williams-Linera 1990a, Laurance & Bierregaard 1996, Gehlhausen *et al.* 2000, Harper & Macdonald 2002, Meiners *et al.* 2002). Some studies have demonstrated that the proximity to a forest edge may cause a greater tree mortality rate (Laurance *et al.* 1998, Laurance *et al.* 2000), changes in vegetation structure (Williams-Linera 1990a, Brothers & Spingarn 1992, Malcolm 1994, Didham & Lawton 1999, Honnay *et al.* 2002) and a reduction in the abundance of woody seedlings (Benitez-Malvido 1998). Additionally, in the long run, forest edges could alter the composition and

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abundance of pollinators, dispersers and potential seed predators which could affect the composition and structure of plant communities (Aizen & Feinsinger 1994, Gascon *et al.* 1999, Restrepo & Vargas 1999, Galetti *et al.* 2003, Kollmann & Buschor 2003).

The Araucaria forest in South Brazil is composed of species from tropical and temperate floras. The Brazilian pine *Araucaria angustifolia* (Bertol.) Küntze is a key species defining its physiognomic features (Rambo 1956). Theses forests quite frequently have interfaces with savanna fields (Teixeira *et al.* 1986). In the past 5000 years Araucaria forests has expanded towards the fields and its expansion coincided with a lower fire frequency (Behling *et al.* 2004). Since the last century, fields have been converted in pastures for cattle ranching and frequently managed with fire. This and other anthropogenic conversions of land led to the destruction and fragmentation of Araucaria forests, which currently occupy only about 20% of its original range (Secretaria Estadual do Meio Ambiente 2001). To date, there is little knowledge about how fragmentation and edge effects could affect plant diversity, community structure and composition of Araucaria forest remnants.

This work investigates how an edge between Araucaria forest and pasture could influence the structure, richness, abundance and composition of woody and herbaceous plants established along this gradient.

Material and methods

Study area – The study area is located at the National Forest of São Francisco de Paula, Rio Grande do Sul State, southern Brazil, at the altitude of 912 m over the sea level. The climate of the region is Wet Temperate with well-distributed rainfalls during the year (Köppen 1936). Mean temperature in São Francisco de Paula is 14.5 °C; mean rainfall is 2,252 mm y^{-1} (Backes 1999). The study site is located along an edge between a forest fragment and a pasture (29°23'- 29°27' S and 50°23'- 50°25' W). The pasture has been managed for more than 50 years through the action of cattle and fire and these activities were suspended five years before the start of this study.

Sampling design – The study was performed at each of the following seven distances from the forest edge: 0 m (edge), 25, 50, 100 and 250 m from the edge into the forest and 5 and 50 m from the edge into the pasture. In each distance, the plant community was sampled in six plots of 5 × 5 m randomly placed within a 100 m long transect. We sampled 42 plots in total (figure 1). In each plot sampled in the forest, all rooted woody plants ≥ 0.5 m in height were identified or collected for later identification. Seedlings of woody species and herbaceous plants < 0.5 m in height were sampled in 1 × 1 m sub-plots placed inside each 5 × 5 m plot. In cases where the complete identification was not possible, individuals were separated in morphospecies. All woody species < 0.5 m in height were considered seedlings. To investigate how species distribution along the studied gradient vary according to life form and light requirement, the studied distances were separated into three categories: field (-50 m and -5 m), edge (0 m, 25 m and 50 m) and forest (100 m and 250 m). Seedlings that were too young to be identified or classified according to their light requirement were not considered for this analysis. These individuals represented 24% of the total number of seedlings sampled. To identify the structural parameters that were altered due to the forest edge, we estimated: understory vegetation cover, soil vegetation cover and maximum canopy height. The understory vegetation cover was estimated according to Malcolm (1994), using a 3 m long pole that was placed every meter inside each 5 × 5 m plot, with a total of 25 points sampled per plot. In each sampled point we registered the number of times the vegetation of the plot touched the pole. Soil vegetation cover was measured in each 1 × 1 m sub-plot by a visual estimation of the amount of vegetation that cover the soil using the following percentage categories: 0 to 20, 21 to 40, 41 to 60, 61 to 80 and 81 to 100. Canopy height was estimated visually using a 2 m long calibration pole as parameter. Species were classified according to their light requirement using information provided by the published Flora Ilustrada Catarinense (Reitz 1965 to 1989). When this information was not available in Reitz (1965-1989) light requirement information was assigned using herbaria data and previous field work experience.

Data analysis – To evaluate possible alterations in floristic composition of woody, seedlings and herbaceous species along the edge gradient studied we performed separate cluster analysis for each life form using the single linkage method.

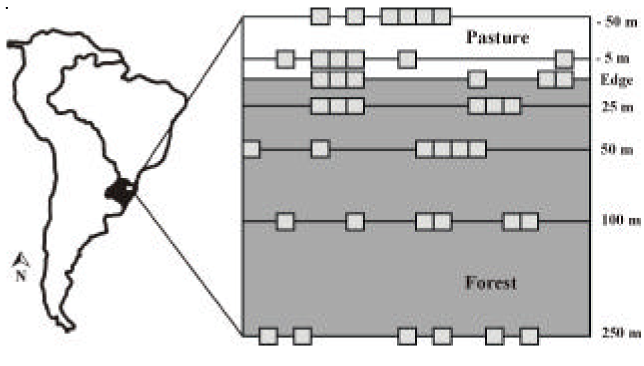

Figure 1. Study site and sampling design of vegetation survey performed along the edge gradient studied. Quadrats represent the 5 × 5 m plots randomly assigned in each distance: -50 m and -5 m from the edge into the field and 0 m, 25 m, 50 m, 100 m and 250 m from the edge into the forest. The study was performed at the National Forest of São Francisco de Paula, Rio Grande do Sul State, South Brazil.

The Euclidian Distance was used for measurements of species relative abundance, while species presence and absence were analysed using the Percent Distance Index. Species richness and the abundance of individuals in each plant category were compared among the different distances from the edge by ANOVA, using the *a posteriori* test of Tukey (Zar 1984).

Results

During the survey 2,040 individuals were sampled and 106 species were recognized (69 genera, 45 families and 22 morphospecies of vascular plants) (table 1). The forest edge and the pasture contained a greater

Table 1. Taxonomical list of species sampled in the study area. Life forms represent: canopy tree (CT); sub-canopy tree (ST); shrub (SH), herb (HB) and probably canopy-tree (PCT). Light requirement represents: L = light demanding; S = shade tolerant and I = indifferent.

Family/Species	Life form	Light requirement
AMARANTHACEAE		
Gomphrena sp.	HB	L
ANACARDIACEAE		
Lithraea brasiliensis Marchand	CT	I
ANONNACEAE		
Rollinia sylvatica (A. St.-Hil.) Mart.	ST	I
APIACEAE		
Eryngium horridum Malme	HB	L
Hydrocotyle sp.	HB	S
Apiaceae 1	HB	
AQUIFOLIACEAE		
Ilex cf. *microdonta* Reissek	ST	S
Ilex paraguariensis A. St.-Hil.	CT	S
ARALIACEAE		
Oreopanax fulvum Marchal	CT	S
ARAUCARIACEAE		
Araucaria angustifolia (Bertol.) Kuntze	CT	I
ASCLEPIADACEAE		
Asclepias curassavica L.	HB	L
ASPLENIACEAE		
Asplenium sp.	HB	S
ASTERACEAE		
Achyrocline satureioides (Lam.) DC.	HB	L
Chaptalia nutans (L.) Pol.	HB	L
Elephantopus mollis Kunth	HB	I
Piptocarpha notata (Less.) Baker	SH	L
Solidago chilensis Meyen	HB	L
Vernonia cf. *flexuosa* Sims	HB	L
Baccharis sp.1	HB	L
Baccharis sp.2	SH	L
Eupatorium sp.1	SH	L
Eupatorium sp.2	SH	L
Pterocaulon sp.	HB	L
BERBERIDACEAE		
Berberis laurina Billb.	SH	L
CAMPANULACEAE		
Triodanis biflora (Ruiz & Pav.) Greene	HB	L
CELASTRACEAE		
Maytenus aquifolium Mart.	ST	L
COMMELLINACEAE		
Commellinaceae 1	PCT	
CONVOLVULACEAE		
Dichondra sp.	HB	L
CUNONIACEAE		
Lamanonia ternata Vell.	CT	L
DENNSTAEDTIACEAE		
Pteridium aquilinum (L.) Kuhn	HB	L
ESCALLONIACEAE		
Escallonia bifida Link & Otto	ST	L
EUPHORBIACEAE		
Sapium glandulatum (Vell.) Pax	CT	L
Sebastiania brasiliensis Spreng.	ST	L
Stillingia oppositifolia Baill. ex Müll. Arg.	ST	S
Sebastiania sp.	ST	L
FLACOURTIACEAE		
Casearia decandra Jacq.	ST	I
Xylosma cf. *tweediana* (Clos) Eichl.	ST	L
Xylosma sp.	ST	L
LAMIACEAE		
Glechon sp.	HB	L
LAURACEAE		
Cinnamomum amoenum (Nees) Kosterm	CT	S
Cryptocarya cf. *moschata* Ness & Mart.	CT	S
Ocotea lancifolia (Schott) Mez	CT	S
Lauraceae 1	PCT	
LOGANIACEAE		
Strychnos brasiliensis (Spreng.) Mart.	SH	L
MELASTOMATACEAE		
Miconia cinerascens Miq.	SH	L
Tibouchina gracilis (Bonpl.) Cogn.	HB	L
MIMOSACEAE		
Desmanthus virgatus (L.) Willd.	SH	L
MONIMIACEAE		
Mollinedia elegans Tul.	SH	S
MYRSINACEAE		
Myrsine umbellata Mart.	CT	L
Myrsine sp.	CT	L

continue

continuation

Family/Species	Life form	Light requirement
MYRTACEAE		
Acca sellowiana (O. Berg) Burret	CT	L
Eugenia psidiiflora O. Berg	ST	S
Calyptranthes concinna DC.	ST	L
Campomanesia xanthocarpa O. Berg	CT	L
Myrceugenia myrcioides (Cambess.) O. Berg	ST	S
Myrcia oligantha O. Berg	ST	I
Myrrhinium atropurpureum Schott	ST	I
Siphoneugena reitzii D. Legrand	ST	L
Myrceugenia sp.	ST	S
Myrtaceae 1	PCT	
Myrtaceae 2	PCT	
Myrtaceae 3	PCT	
Myrtaceae 4	PCT	
ORCHIDACEAE		
Orchidaceae 1	HB	
OXALIDACEAE		
Oxalis sp.1	HB	L
Oxalis sp.2	HB	L
PODOCARPACEAE		
Podocarpus lambertii Klotzsch ex Endl.	CT	L
POLYPODIACEAE		
Polypodium sp.	HB	S
PROTEACEAE		
Roupala brasiliensis Klotzsch	CT	S
RHAMNACEAE		
Rhamnus sphaerosperma Sw.	ST	L
RUBIACEAE		
Rudgea parquioides (Cham.) Müll. Arg.	ST	S
RUTACEAE		
Zanthoxylum rhoifolium Lam.	CT	I
SAPINDACEAE		
Allophylus edulis (A. St.Hil., Cambess. & A. Juss.) Radlk.	ST	I
Cupania vernalis Cambess.	CT	L
Matayba elaeagnoides Radlk.	CT	I
SOLANACEAE		
Solanum americanum Mill.	HB	L
Brunfelsia sp.	SH	S
SYMPLOCACEAE		
Symplocos uniflora (Pohl) Benth.	ST	L
THEACEAE		
Gordonia fruticosa (Schrad.) H. Keng	ST	S
THELIPTERIDACEAE		
Thelipteris sp.	HB	I
THYMELAEACEAE		
Daphnopsis racemosa Griseb.	SH	I
ULMACEAE		
Celtis cf. *iguanaea* (Jacq.) Sarg.	ST	L
VERBENACEAE		
Lippia ramboi Moldenke	SH	L
WINTERACEAE		
Drimys brasiliensis Miers	ST	I
MORPHOSPECIES		
Herbs (1 – 5)	HB	
Woody (1 – 6)	PCT	
Seedling (1 – 11)	PCT	

abundance of light-demanding individuals than the forest interior, which had a dominance of shade-tolerant individuals (figure 2A). However, the proportion of light demanding species tended to be similar between forest and edge, although we found a trend for a higher proportion of light demanding species at the edge zone for most of the plant life forms studied (figure 2B). Plant species that were classified as indifferent in relation to their light requirements tended to be homogeneously distributed throughout the gradient. We found a greater abundance of trees at the edge than at the forest interior, moreover, sub-canopy trees were more frequent than canopy trees. At the pasture, herbs predominated; seedlings of woody species were scarce, and shrubs and trees were absent (figure 2A).

Woody species – There was a higher abundance ($F_{4.25}$ = 7.5, P < 0.001, figure 3A) and richness ($F_{4.25}$ = 5.09, P < 0.01, figure 3B) of woody species at the edge (0 m) in relation to the distances 25 and 50 m from the edge into the forest. The cluster analysis revealed a continuous change in woody species composition along the edge gradient studied for both abundance and presence/absence (figure 5A). The greatest similarity occurred between the distances 100 m and 250 m into the forest. The forest interior was then more similar to the distance 50 m followed by the distance 25 m from the edge towards the forest. The edge (0 m) contained a distinct composition of woody plant species in relation to all other distances studied. We found 56 taxa of woody plants (table 2). The most abundant woody species were *Stillingia oppositifolia* (350 individuals), *Siphoneugena reitzii* (265), *Rudgea parquioides* (170) and *Casearia decandra* (107). These species differed in their spatial distribution along the edge gradient. *S. reitzii* occurred more often near the edge, *S. oppositifolia* and *R. parquioides* tended to occur inside the forest (100 and 250 m) while *C. decandra* was homogeneously distributed in all studied distances (table 2). Twelve woody species occurred exclusively at the edge (0 m) and five species occurred exclusively in the forest interior (100 and 250 m), but these species tended to be rare. Sixteen species were able to use most of the studied gradient (table 2).

Seedlings – Seedling abundance ($F_{4.25}$ = 6.4, P < 0.01, figure 4A) and richness ($F_{4.25}$ = 5.1, P < 0.01, figure 4B) were significantly higher at the edge (0 m). Moreover, there was a sharp decrease in abundance at the pasture and the distance 25 m into the forest. The cluster analysis using abundance and presence/absence revealed clear alterations in species composition of seedlings at the edge (0 m) in relation to the pasture and forest interior. Moreover, three distinct groups were found: 1) the edge, 0 m; 2) the forest, made up by the distances 50 m, 100 m and 250 m and 3) the distances -50 m, -5 m (pasture) and 25 m (figure 5B). We found 41 taxa of woody seedlings (table 3). The most abundant seedling species that occurred were *Siphoneugena reitzii* (29 individuals), *Myrsine* sp. (25), Seedling 1 (23) and *Stillingia oppositifolia* (23). *S. reitzii* and *S. oppositifolia* coincided with the most abundant adult species (table 3). Six species of seedlings were able to establish in the pasture, occurring exclusively at this area: *Escallonia bifida*, *Baccharis* sp.2, *Desmanthus virgatus*, *Eupatorium* sp.1 and *Eupatorium* sp.2 all typical pioneer species, and *Podocarpus lambertii*, a light-demanding tree that frequently occurs inside the forest. Six morphospecies occurred exclusively at the edge (0 m), five exclusively inside the forest at 100 and 250 m, and 14 species occurred along the whole gradient between edge and forest interior (table 3).

Herbaceous plants – The abundance of herbaceous plants was significantly greater at the edge (0 m) in relation to all other considered distances, with sharp decreases in the field and inside the forest ($F_{4.25}$ = 4.2, P < 0.01, figure 4C). Richness of herbaceous plants was greater in the field and at the edge (0 m), decreasing

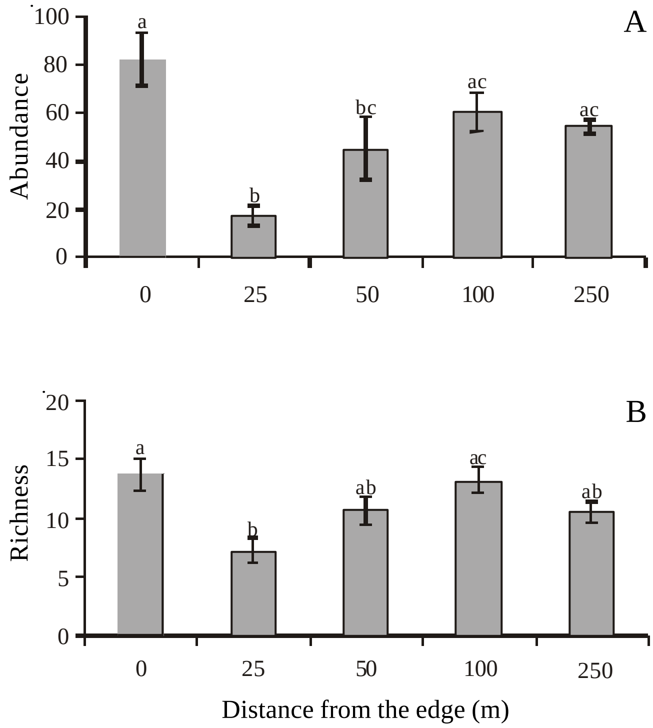

Figure 3. Abundance (A) and richness (B) of woody plants (mean ± 1 standard error) at different distances from the forest edge. Distinct letters indicate significant differences among distances. The study was performed at the National Forest of São Francisco de Paula, Rio Grande do Sul State, South Brazil.

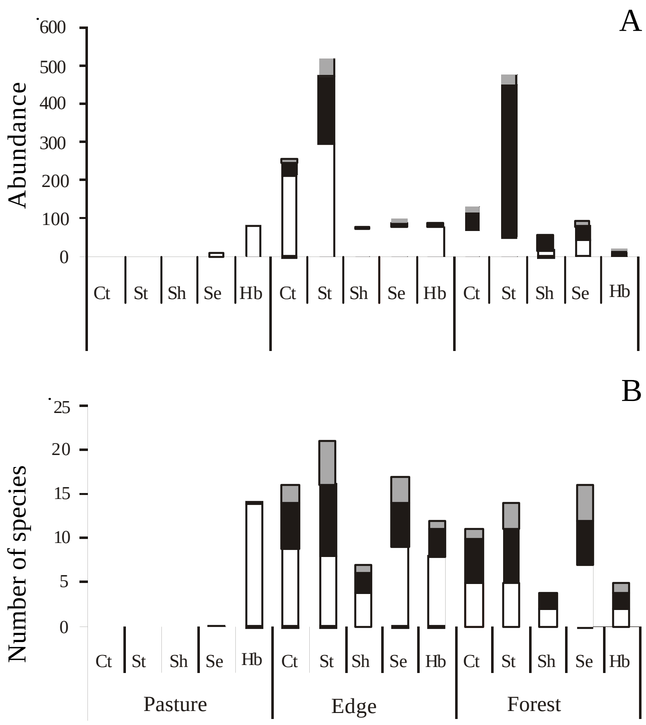

Figure 2. Number of individuals (A) and number of species (B) according to their light requirement (□ = light-demanding; ■ = shade-tolerant; ■ = indifferent), and life form (Ct = tree; St = small tree; Sh = shrub; Se = seedling; Hb = herb) found along the three main environmental categories studied: pasture, edge and forest. The study was performed at the National Forest of São Francisco de Paula, Rio Grande do Sul State, South Brazil.

Table 2. Percentage of individuals of woody species in relation to the total number of individuals per species (Total) occurring at the following distances from the forest edge: 0 m, 25 m, 50 m, 100 m and 250 m. Light requirements are: L = light demanding; S = shade tolerant and I = indifferent.

Species	Light requirement	Individuals for each distance (%)					Total
		0 m	25 m	50 m	100 m	250 m	
Acca sellowiana	L	100					2
Allophylus edulis	S	100					8
Berberis laurina	L	100					3
Celtis cf. *iguanaea*	L	100					1
Ilex cf. *microdonta*	S	100					2
Lithraea brasiliensis	I	100					7
Rhamnus sphaerosperma	L	100					1
Sapium glandulatum	L	100					2
Symplocos uniflora	L	100					2
Woody 3		100					1
Woody 4		100					1
Woody 5		100					1
Lamanonia ternata	L		100				2
Myrtaceae 2			100				3
Cinnamomum cf. *amoenum*	S			100			1
Myrtaceae 4				100			1
Oreopanax fulvum	S				100		1
Woody 1					100		2
Woody 2					100		1
Woody 6					100		1
Xylosma sp.	L					100	3
Piptocarpha notata	L	80	20				5
Daphnopsis racemosa	I	50	50				8
Drimys brasiliensis	I	50	50				2
Myrsine umbellata	L	90		10			29
Rollinia sylvatica	I	62	31	8			13
Calyptranthes concinna	L	64	18	9	9		11
Araucaria angustifolia	L	57	7	25	11		28
Lippia ramboi	L	86				14	7
Siphoneugena reitzii	L	82	4	9	4	2	265
Podocarpus lambertii	L	56	12	20	8	4	25
Myrsine sp.	L	65	7	4	22	2	91
Ocotea lancifolia	S	56	11	11	17	6	18
Miconia cinerascens	L	66	4	7	16	8	76
Myrrhinium atropurpureum	I	35	6	47	12		17
Casearia decandra	I	19	21	17	33	10	107
Rudgea parquioides	S	5	13	9	31	42	170
Xylosma cf. *tweedianum*	L	33		67			3
Myrceugenia myrcioides	S	13			50	38	8
Myrcia oligantha	I	6	6	33		56	18
Ilex paraguariensis	S	33				67	3
Gordonia fruticosa	S	20			60	20	5
Cryptocarya cf. *moschata*	S			60	20	20	10
Eugenia psidiiflora	S		31	15	23	31	26
Campomanesia xanthocarpa	L			84	8	8	37
Myrtaceae 3			25	17	50	8	12
Mollinedia elegans	S		3		50	47	32

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Species	Light requirement	Individuals for each distance (%) 0 m	25 m	50 m	100 m	250 m	Total
Stillingia oppositifolia	S			29	34	37	350
Roupala brasiliensis	S			26	42	32	31
Sebastiania brasiliensis	L			20	43	37	30
Myrceugenia sp.	S			6	65	29	17
Matayba elaeagnoides	I			17	54	29	24
Cupania vernalis	L			25	25	50	4
Maytenus aquifolium	L			33		67	3
Brunfelsia sp.	S			9		91	11
Myrtaceae 1					50	50	2

from 25 m on into the forest ($F_{4.25} = 4.7$, $P < 0.01$), however, the Tukey test only detected a significant difference between the edge (0 m) and the distance 25 m into the forest (figure 4D). The cluster analysis for abundance and presence/absence demonstrated the occurrence of distinct assemblages of herbaceous plants at the edge (0 m) and 5 m inside the pasture. We found a greater similarity in the assemblages of herbaceous plants occurring inside the forest interior (figure 5C). We found 32 taxa of herbaceous plants (table 4). The most abundant herbaceous species that occurred on the area were *Chaptalia nutans* and *Eryngium horridum.* This species presented differences in their spatial distribution along the edge gradient, individuals of *C. nutans* occurred only in the forest, and 80% of them occurred at the edge (0 m). *E. horridum*, however, occurred only in the pasture (table 4). We registered 12 morphospecies that occurred exclusively in the pasture, 10 morphospecies prevailed at the edge (0 m) and only 4 morphospecies were found exclusively inside the

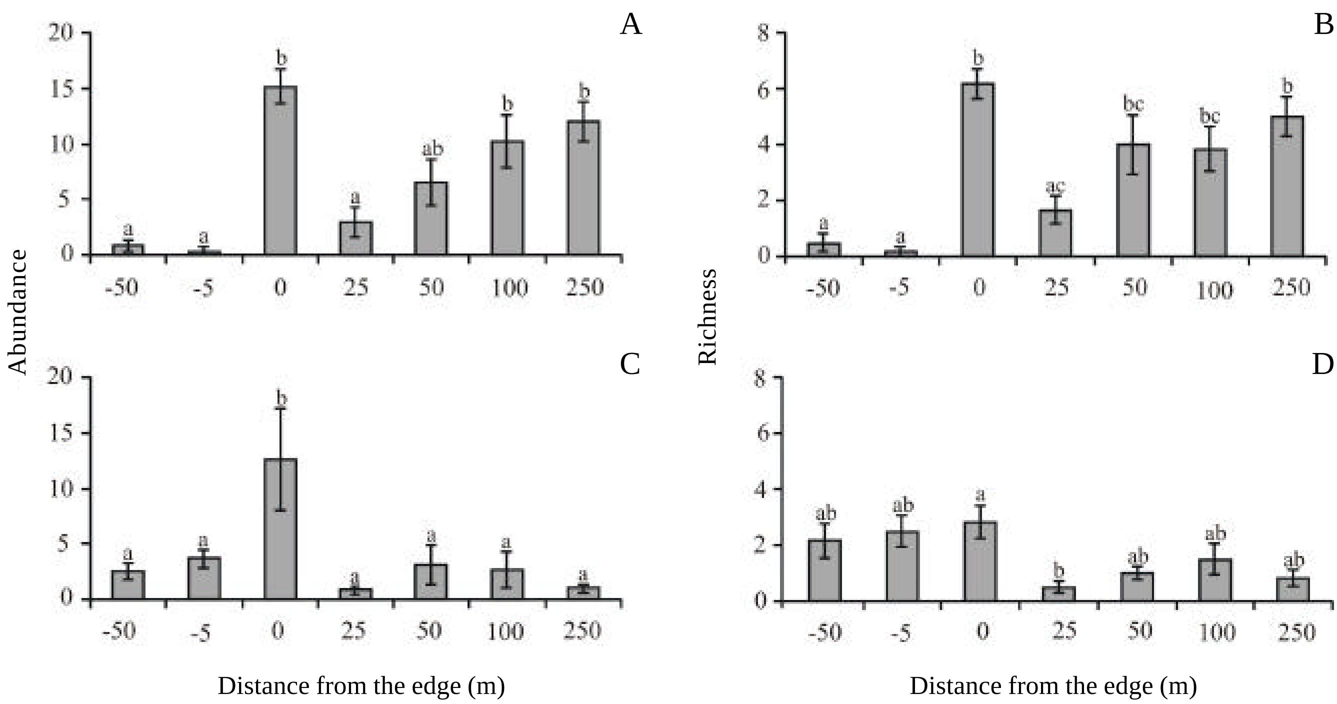

Figure 4. Abundance (A) and richness (B) of woody seedlings and abundance (C) and richness (D) of herbaceous plants (mean ± 1 standard error) at different distances from a forest edge. Distinct letters indicate significant differences among distances. The study was performed at the National Forest of São Francisco de Paula, Rio Grande do Sul State, South Brazil.

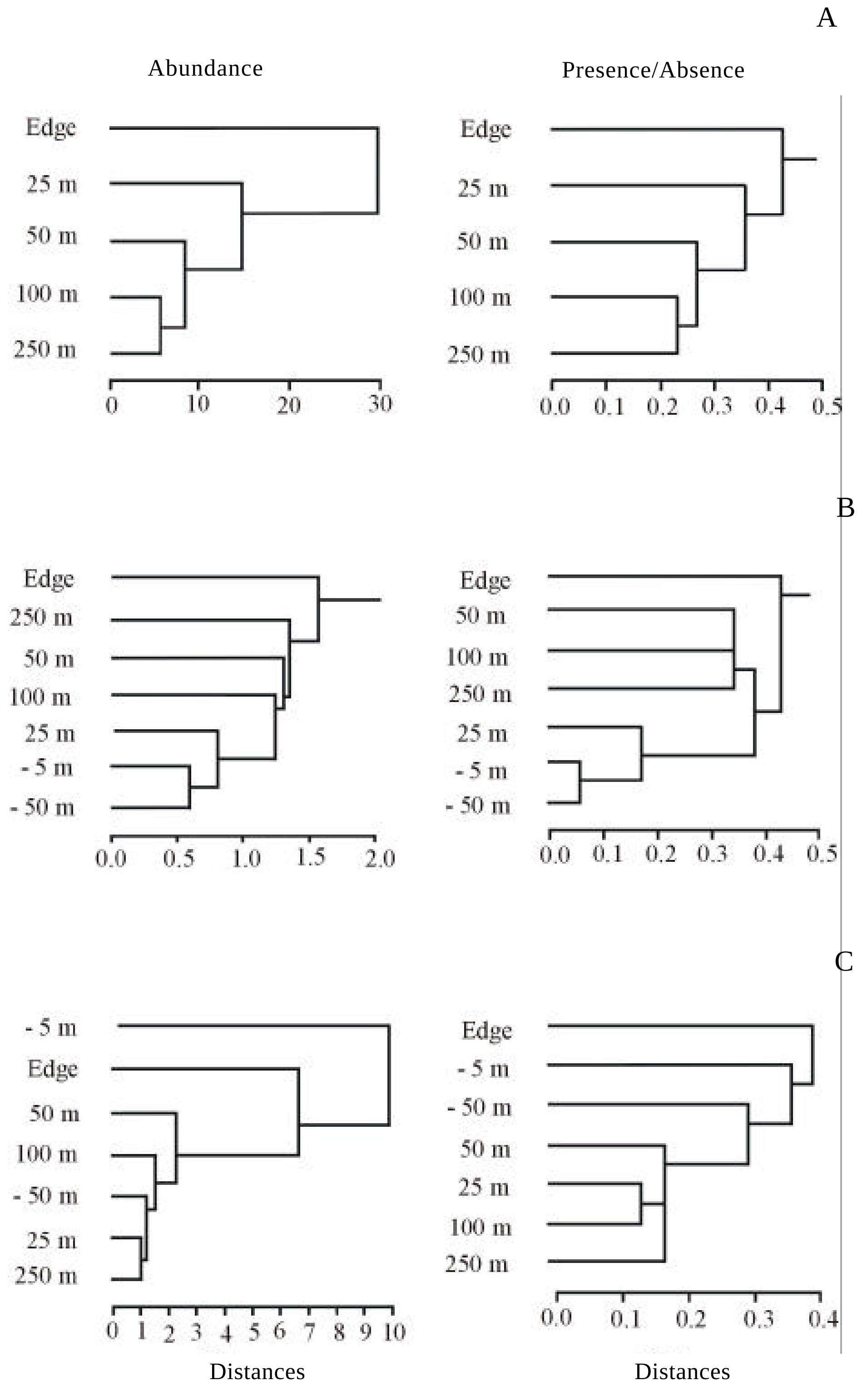

Figure 5. Cluster analysis looking at similarity by abundance and by presence/absence of species composition of Woody (A), Seedlings (B) and Herbs (C) at different distances from the forest edge. The study was performed at the National Forest of São Francisco de Paula, Rio Grande do Sul State, South Brazil.

Table 3. Percentage of individuals of woody seedlings in relation to the total number of individuals per species (Total) occurring at the following distances from the forest edge: 0 m, 25 m, 50 m, 100 m and 250 m. Light requirements are: L = light demanding; S = shade tolerant and I = indifferent.

Species	Light requirement	Individuals for each distance (%)							Total
		-50 m	-5 m	0 m	25 m	50 m	100 m	250 m	
Escallonia bifida	L	100							2
Podocarpus lambertii	L	100							2
Baccharis sp.2	L	50	50						2
Desmanthus virgatus	L	75	25						4
Eupatorium sp.1	L	33	67						3
Eupatorium sp.2	L		100						1
Calyptranthes concinna	L			100					1
Lamanonia ternata	L			100					5
Myrsine umbellata	L			100					7
Sebastiania brasiliensis	L			100					5
Seedling 2				100					1
Comellinaceae 1				100					1
Lauraceae 1					100				1
Myrtaceae 2					100				1
Allophylus edulis	S					100			2
Zanthoxylum rhoifolium	I					100			1
Seedling 11						100			1
Cupania vernalis	L						100		1
Sebastiania sp.	L						100		12
Brunfelsia sp.	S							100	2
Lithraea brasiliensis	I							100	4
Seedling 9								100	1
Myrrhinium atropurpureum	I			35		18		47	17
Strychnos brasiliensis	L			25		13		63	8
Seedling 5				50		50			2
Ocotea lancifolia	S			33			33	33	6
Miconia cinerascens	L			50			43	7	14
Myrsine sp.	L			44	16	8	32		25
Seedling 1				26	17	9		48	23
Campomanesia xanthocarpa	L			17		50	6	28	18
Rudgea parquioides	S			20		20	40	20	5
Seedling 6				6		18	41	35	17
Siphoneugena reitzii	L			79			10	10	29
Casearia decandra	I			60			40		5
Seedling 8					40	20		40	5
Seedling 7					33	67			3
Roupala brasiliensis	S					20	40	40	5
Seedling 4						67		33	3
Stillingia oppositifolia	S					9	57	35	23
Seedling 3						67	33		3
Seedling 10						50	50		2

forest. Two morphospecies found in the field were able to invade the forest edge and only *Pteridium aquilinum* was able to occur in the pasture and in the forest interior (table 4).

Structural parameters – There was a significant increase in vegetation cover of understory plants at the edge (0 m) in relation to the other distances studied in the forest ($F_{4.25}$ = 10.3, P <0.001, figure 6A). However, neither canopy height ($F_{4.25}$ = 0.9, P > 0.05, figure 6B) nor soil vegetation cover ($F_{4.25}$ = 1.4, P > 0.05, figure 6C) were

Table 4. Percentage of individuals of herbs in relation to the total number of individuals per species (Total) occurring at the following distances from the forest edge: 0 m, 25 m, 50 m, 100 m and 250 m. Light requirements are: L = light demanding; S = shade tolerant and I = indifferent.

Species		Individuals for each distance (%)							
	Light requirement	-50 m	-5 m	0 m	25 m	50 m	100 m	250 m	Total
Glechon sp.	L	100							2
Tibouchina cf. *gracilis*	L	100							3
Vernonia cf. *flexuosa*	L	100							1
Asclepias curassavica	L		100						1
Eryngium horridum	L		100						53
Eupatorium sp.2	L		100						1
Gomphrena sp.	L		100						5
Herb 1			100						11
Achyrocline satureioides	L			100					1
Elephantopus mollis	I			100					4
Solanum americanum	L			100					3
Oxalis sp.2	L			100					4
Pterocaulon sp.	L			100					1
Apiaceae 1				100					8
Herb 2				100					4
Herb 4				100					1
Polypodium sp.	S					100			1
Herb 5						100			1
Thelipteris sp.	I						100		7
Orchidaceae 1								100	2
Baccharis sp.1	L	75	25						4
Desmanthus virgatus	L	75	25						4
Solidago chilensis	L	14	86						7
Eupatorium sp.1	L	33	67						3
Triodanis biflora	L	50		50					2
Oxalis sp.1	L		25	75					4
Pteridium aquilinum	L		67				33		3
Chaptalia nutans	L			80	9	6	6		54
Hydrocotyle sp.	S			50			38	13	8
Herb 3				33		33		33	3
Dichondra sp.	L			8		92			13
Asplenium sp.	S					25	50	25	4

significantly different among the different distances from the forest edge.

Discussion

We registered a clear pattern of changes in the plant community due to edge effects that occurred in the first 50 m from the edge into the forest. Such changes consist of a decrease in understory vegetation cover and a decrease in abundance and richness of woody plants, seedlings and herbs from 25 to 50 m into the forest. Besides, there was a significant increase of these former parameters at the interface between field and forest (distance 0 m). We also found continuous changes in floristic composition along the edge. The proportion of individuals and species found for each life form was similar along the forest gradient studied, however, there was an increase in light-demanding individuals at the edge for all studied life forms. The extension of such alterations in plant communities due to edge effects is comparable to other works done in Brazil and other contries, in which penetration of edge effects varied from 15 to 60 m into the forest (Williams-Linera 1990a, 1990b, Malcolm 1994, Young & Mitchell 1994, Baldi 1999, Gehlhausen *et al.* 2000, Harper & Macdonald 2002, Honnay *et al.* 2002).

Several factors may have influenced the alterations found in the studied forest edge. Distinct abiotic conditions between forest and edge (Kapos 1989, Matlack 1993) commonly cause changes in species composition (Williams-Linera 1990a, Gehlhausen *et al.* 2000, Oosterhoorn & Kappelle 2000, Honnay *et al.* 2002), vegetation structure (Williams-Linera 1990a, Malcolm 1994, Young & Mitchell 1994, Cadenasso & Pickett 2001) and tree mortality rate (Laurance *et al.* 1998, Mesquita *et al.* 1999, Laurance *et al.* 2000). In this study grazing and cattle trampling may have caused differential mortality of herbs and woody seedling as observed by Mauhs & Backes (2002) in a similar study area. Additionally, the occasional penetrations of fire may cause significant changes in vegetation structure and composition at the edge affected area that in this study penetratres, at least, up to 50 m inside the forest (Cochrane & Laurance 2002). Another factor of great importance that we have observed was the action of strong sporadic winds that caused great damage to vegetation and high mortality of canopy trees at the edge.

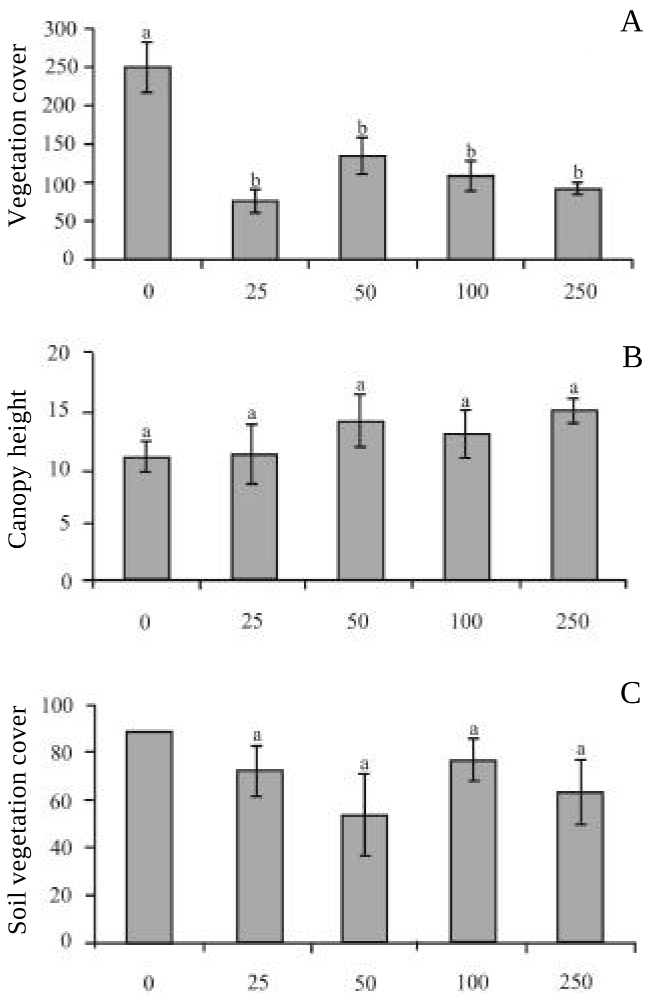

Figure 6. Mean ± 1 standard error of vegetation cover of understorey plants, (A), canopy height (B) and soil vegetation cover (C) at different distances from a forest edge. Distinct letters indicate significant differences among distances. The study was performed at the National Forest of São Francisco de Paula, Rio Grande do Sul State, South Brazil.

Such alterations on vegetation structure may change light intensity nearby a forest edge (Williams-Linera 1990b, Malcolm 1994). Benitez-Malvido (1998) recorded lower seedling abundance at the edge of tropical forest fragments. We found, however, an accentuated increase of seedlings, as found by Sizer & Tanner (1999), as well as a peak in richness and abundance of woody plants and herbs at the edge (0 m). This pattern was mainly due to the proliferation of *S. reitzii*, and *C. nutans*, typical light demanding species. Therefore, the colonization of this species at the edge was probably improved by high light intensity (Kapos 1989, Matlack 1993, Baldi 1999). However, shade-tolerant species that were abundant in the survey such as *R. parquioides* and *S. oppositifolia*, did not occur at the edge. Continuous alterations in the plant community composition along forest edges were also found by Gehlhausen *et al.* (2000).

Only six seedlings of woody species established in the field, suggesting that forest invasion into the field occurs at slow rates, considering that the studied pasture has been abandoned for five years. We believe that there are three main causes for this pattern. First, soil conditions in this pasture may have been jeopardized by the use of fire. Second, we found a high density of *E. horridum* in the pasture, and this species is known to be very abundant, and outcompete previously existing species in situations where fields are managed with fire (Boldrini 1997). Third, other works performed at the study area have found high seed predation rates of woody plant species colonizing this abandoned pasture, indicating that post dispersal hazards may limit tree establishment (Baldissera & Ganade 2005).

The invasion of herbs from the field into the forest was extremely reduced. From the 15 species registered in the field only two occurred at the forest edge. Therefore, the increase in abundance of herbs at the edge may be a consequence of the migration of light-demanding species coming from the forest interior. These results suggest that the invasion of species from the field towards the forest is relatively slow compared to other studies (Brothers & Spingarn 1992, Cadenasso

& Pickett 2001). This pattern may be due to the high density of vegetation cover at the forest edges that could function as a physical barrier, limiting the arrival of wind dispersed seeds into the forest (Williams-Linera, 1990a, Malcolm 1994, Dihdam & Lawton 1999, Cadenasso & Picket 2001, Honnay *et al.* 2002). Additionally, the edge became a place improper for the invasion of light demanding herbs due to the proliferation of branches and the establishment of a dense shrub and tree community (Brothers & Spingarn 1992).

All these changes in vegetation structure and composition along this edge of Araucaria forest and field may have great consequences over the fauna diversity (Murcia 1995). These results bring important information for management and conservation plans of fragmented areas of Araucaria forest. An extension of 50 m around the forest fragment should be considered altered by edge effects. Therefore, fragments with a high edge/interior ratio should not be characterized as intact native forest, and management plans for conserving forest remnants should give preference to areas with low edge/interior ratio (Lovejoy *et al.* 1986).

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