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Abundance and Distribution of Native and Alien Grasses in a “Cerrado” (Brazilian Savanna) Biological Reserve

V. R. Pivello, V. M. C. Carvalho, P. F. Lopes, A. A. Peccinini, and S. Rosso
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ABSTRACT

Several species of African grasses brought to Brazil as cattle forage have spread widely, outcompeting native herb species. The open forms of Brazilian savanna (“campo cerrado” and “campo sujo”) are the most affected by such invasions, because their structure is open, permitting enough sunlight into the lower strata. The invasion of alien forage grasses occurs in almost every cerrado nature reserve. This study was carried out in the “Cerrado de Emas Biological Reserve,” Pirassununga, São Paulo State, Brazil, with the following objectives: (a) to compare the abundance of native and alien grass species; (b) to verify the importance of such alien grasses in the community; (c) to identify distribution patterns for the alien grass species in a gradient from the edge (highly disturbed) to the center (less disturbed) of the reserve; and (d) to explore the distribution of native and alien grasses in the search for possible competitive interactions. Using the “point method,” a total of 260 points was sampled and 52 species were recorded. The four most frequent species (FA = absolute frequency) were two native (Echinolaena inflaxa [Poir.] Chase [FA = 38.85%] and Diandrostachya chrysothrix [Nees] Jacqes Felix [FA = 15.38%]) and two alien African species (Melinis minutiflora Beav. [FA = 33.08%] and Brachiaria decumbens Stapf [FA = 13.85%]). M. minutiflora and E. inflaxa had higher values of absolute vigor (67.69 and 59.62%, respectively), relative vigor (28.16 and 24.80%, respectively), and cover (100.77 and 98.47, respectively), indicating higher biomasses and densities and their dominance in the community. B. decumbens presented the highest number of contacts per point, showing the highest stratification. To detect possible edge-center distribution gradients, correspondence analysis was done, initially using all the recorded species and subsequently only the four more frequent grasses, with similar results: (a) the alien grasses, especially M. minutiflora, did not show a distinct distribution gradient from edge to center, but occurred over the whole reserve; (b) no distinct ecotonal band around the reserve (edge-belt) was detected, the whole reserve seeming to be “ecotonal”; and (c) E. inflaxa and M. minutiflora showed similar phytosociological patterns, and spatial distribution; association between these two species was statistically significant.

RESUMO

Diversas gramíneas exóticas, trazidas ao Brasil como forrageiras, espalharam-se por grandes extensões, deslocando espécies nativas, graças a seu maior poder competitivo. Os ecossistemas de campo cerrado e campo sujo são os que mais sofrem a invasão destas gramíneas heliófitas, por serem naturalmente abertos, permitindo suficiente insolação no estrato herbáceo. Em praticamente todas as unidades de conservação que visam proteger os cerrados, a invasão de gramíneas forrageiras exóticas é evidente. Com os objetivos de: (a) comparar a abundância das espécies de gramíneas nativas e exóticas; (b) verificar a importância destas gramíneas na comunidade; (c) identificar padrões de distribuição das gramíneas exóticas ao longo de transectos borda/centro; e (d) explorar a distribuição das gramíneas nativas e exóticas na pesquisa de eventuais interações competitivas, este estudo foi realizado numa área de campo cerrado na Reserva Biológica do Cerrado de Emas, Pirassununga, Estado de São Paulo, Brazil. Usando o “método dos pontos”, um total de 260 pontos foram amostrados, com 52 espécies. Desse total, 4 gramíneas tiveram frequências absolutas (FA) muito superiores às demais espécies, sendo 2 delas nativas: Echinolaena inflaxa (Poir.) Chase (FA = 38,85%) e Diandrostachya chrysothrix (Nees) Jacqes Felix (FA = 15,38%), e 2 exóticas: Melinis minutiflora Beav.(FA = 33,08%) e Brachiaria decumbens Stapf (FA = 13,85%). A análise fitossociológica mostrou ainda que M. minutiflora e E. inflaxa apresentaram maiores valores em vigor absoluto (67,69 e 59,62%, respectivamente), em vigor relativo (28,16 e 24,80%, respectivamente) e índice de cobertura (100,77 e 98,47 respectivamente), indicando maiores biomassas e densidades, e sua dominância na comunidade. Brachiaria decumbens apresentou maior média de toques, demonstrando maior estratificação. A fim de reconhecer eventuais gradientes de distribuição das bordas para o centro, foi feita a análise de correspondência usando-se primeiramente todas as espécies e posteriormente apenas as 4 gramíneas mais frequentes, com resultados similares: (a) as gramíneas exóticas não apresentaram um gradiente nítido de distribuição das bordas para o centro, distribuindo-se por toda a reserva, principalmente M. minutiflora; (b) não foi evidenciada uma faixa ecotonal distinta nas bordas da reserva, parece não estar toda ela na condição de ecotônico; (c) E. inflaxa e M. minutiflora apresentaram padrões fitossociológicos e de distribuição espacial semelhantes; associação entre elas foi demonstrada estatisticamente.

Key words: African grasses; alien plants; biological invasions; Brachiaria decumbens; Brazil; cerrado; edge effect; habitat fragmentation; Melinis minutiflora; savanna.

1 Received 3 December 1996; revision accepted 17 June 1997.
Invasive alien species are a major threat to biodiversity as they are able to invade and modify environmental conditions severely, either by displacing native species or by changing the conditions of soil, microclimate, fire and/or water regimes, and food resources available to fauna (MacKinnon et al. 1986, Anable et al. 1992, D’Antonio & Vitousek 1992, WCMC 1992, Giv- en 1994, Cronk & Fuller 1995, Le Maître et al. 1996, Nilsson & Grelsson 1996). Among plant invaders, grasses are especially important because they can spread very easily, and are often very competitive against native plants; most tolerate fire and are able to modify severely the environment where they dominate (D’Antonio & Vitousek 1992). Anable et al. (1992) report a notable case of a very invasive grass, Eragrostis lehmanniana, in the Arizona arid grassland. That grass invaded, on average, more than 2500 ha/yr, from 1932 to 1989; at that time, its biomass was more than 90 percent of the grass biomass in the area; it being able to produce 2–4 times more biomass than native grasses.

The great majority, if not all, the nature reserves created to protect the Brazilian savannas (“cerrados”) today are subject to invasion by alien grass species, notably Melinis minutiflora Beauv., Brachiaria decumbens Stapf, Hyparrhenia rufa (Nees) Stapf, Panicum maximum Jacq., and Andropogon gayanus Kunth (Coutinho & Hashimoto 1971, Filgueiras 1990, Pivello 1992, Klink 1994, 1996). According to Pivello (1992), the most intractable management problem for cerrado nature reserves, pointed out by 26 scientific researchers and nature reserve managers interviewed in Goiás and São Paulo States (Brazil), is invasion by alien grasses, particularly Melinis minutiflora (Fig. 1, Table 1).

The grass species cited above, mostly of African origin (Filgueiras 1990), were introduced to Brazil for their high forage value, except P. maximum which was accidentally brought into the country (Klink 1996). Having found suitable climate and soil conditions in cerrados, these species have spread rapidly, outcompeting native herbs. All of them are classified by Filgueiras (1990) as “very aggressive” because of their potential to colonize new sites; that author includes them at the top of an “aggressiveness ranking.”

McClintock (1987, cited by Given 1994) classifies invader plants under three categories: (1) those that benefit from management practices developed by humans for cultivated species and,
TABLE 1. Plant species identified as main invaders in cerrado nature reserves, in São Paulo and Goiás States, according to 26 scientific researchers and nature reserve managers (after Pivello 1992).

<table>
<thead>
<tr>
<th>Main invader species</th>
<th>Family</th>
<th>Interviewed people n²</th>
<th>percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melinis minutiflora</td>
<td>Poaceae</td>
<td>26</td>
<td>100</td>
</tr>
<tr>
<td>Brachiaria spp.</td>
<td>Poaceae</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>Hyparrhenia rafa</td>
<td>Poaceae</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>Pinus elliottii*</td>
<td>Pinaceae</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Panicum maximum</td>
<td>Poaceae</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Pteridium aquilinum</td>
<td>Pteridaceae</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Aristida sp.</td>
<td>Poaceae</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Cuscuta sp.</td>
<td>Cuscutaceae</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

* Only in those nature reserves surrounded by Pinus elliottii plantations.

therefore, are restricted to urban and agricultural areas; (2) those that occupy disturbed, degraded, or abandoned lands, being marginal to natural areas (in many of these cases, however, the native species displaced by the disturbance cannot re-establish after the establishment of aliens and the site serves as a colonization nucleus for undisturbed areas); and (3) those introduced for economic purposes but having escaped human control, being highly aggressive, and able to invade extensively both disturbed and natural areas. Those African grasses invading cerrados seem to belong to this third category.

According to Klink (1996), some of these grasses do not appear to invade undisturbed natural areas and should be classified as colonizers rather than invaders. However, it has been observed that once such grasses are established in open cerrados, recolonization of the area by native herbs becomes very difficult. The terminology applied to nonnative plants that spread to natural areas varies according to different authors; some attempts to produce a unifying classification of such species are presented by Rejmanek (1995) and Pysek (1995). In this article, the species being considered will be treated as invader alien species.

One of the parameters that has been used to estimate the degree of disturbance in natural communities and its level of fragility (the opposite of stability, following Nilsson & Grelsson 1996) is the level of infestation by alien species (Filgueiras 1990, Nilsson & Grelsson 1996). This study attempts to estimate the degree of environmental disturbance on a cerrado biological reserve by analyzing alien grass species distribution and abundance, as well as comparing them to native grasses. The study had the following specific objectives: (a) to quantify the abundance and distribution of native and alien herb/subshrub species; (b) to compare the present importance of native and alien grasses in a disturbed community, using selected phytosociological parameters; (c) to identify distribution patterns of alien grasses along edge to center transects; and (d) to explore associations between alien and native grasses.

STUDY AREA

This study was conducted in the Cerrado de Emas Biological Reserve, at Pirassununga Municipality, São Paulo State, Brazil (47°23′W, 21°58′S). The reserve is separated in two parts by a road, one being ca 14.5 ha and fenced, where this study was carried out, and another ca 35 ha and not fenced (Fig. 2). This small reserve is a remnant of Cerrado de Emas, which formerly covered an extensive, continuous area.

Prior to 1950, the region was covered by cerrado landscape, which included a gradient from open savanna forms, the “campo-sujo” (grassy savanna) where human influence had been greater or the soil was poorer, to closed savannas, the “cerradão” (woodland savanna) on the more protected and richer soils; gallery forests occurred along the rivers (the cerrado physiognomic classification adopted here follows Coutinho [1978]). Cerrado de Emas Biological Reserve is covered mostly by a “campo-cerrado” physiognomy (open savanna with arboreal elements), having on one side a cerradão (woodland savanna) portion developed after 40–50 years of fire protection, and on the opposite side, extending to Mogi-Guaçu River, a transitional cerrado to gallery forest vegetation (Fig. 2).

The regional climate is Koeppen’s Cwa, humid and warm with a dry winter, or, according to Walter and Lieth, type II (i.e., tropical, with wet summer and dry winter). The relief is gently rolling, formed basically by extensive and flat-topped hills. The predominant soil type is Red-Yellow Latosol, acid, and ferruginous (Pivello-Pompéia 1985).

METHODS

Only the campo cerrado physiognomy of the reserve was considered in this study (Fig. 3), because it has an open physiognomic aspect that is more susceptible to grass invasion.

The “point method” was used to sample the
herb/subshrub layer. This involved dropping a thin metal, graded stick vertically into the soil, and then identifying, counting, and recording the species touched by the stick at different heights, as described by Mantovani and Martins (1990). This method was developed specifically for surveying the herb/subshrub layer. It is comparatively rapid and causes little disturbance to the vegetation.

Samples were taken along six radial transects, starting from a point in the center of the campo-cerrado patch and ending at points randomly defined on the reserve perimeter. The distance between sampling points along the transects was 4 m (Fig. 3).

A 1-m tall, 2.5-mm diameter metal stick, graded in cm, was used. At each point, we verified the species touched by the stick, the number of contacts, and their heights. A total of 260 points was sampled and every 5 points were then grouped. This grouping was made because there were many null and single occurrences when the original points were treated as samples.

Botanical material was dried and identified. A phytosociological analysis was carried out, following the parameters presented by Mantovani and Martins (1990). Because the majority of alien herbs in the area were grasses which were much more
Cerrado de Emas Biological Reserve

FIGURE 3. Experimental design adopted in this study. The transects A, B...F were all located in a campo cerrado physiognomy (TMC = cerrado/gallery forest transition; CC = campo cerrado; CD = cerradão).

abundant than other taxonomic groups, subsequent analyses concentrated on the grasses.

An exploratory analysis of correspondence was made to substantiate possible edge to center distribution gradients for the alien grasses, which could indicate edge effects (ter Braak 1987) that included qualitative (number of occurrences) and quantitative (number of contacts) parameters. The first analysis was for all the recorded species and the subsequent for only the four grasses, whose frequencies were much higher than other species. A more detailed distribution analysis was developed for these four grasses.

To depict the spatial distribution of the most abundant grasses in the field, the number of contacts in each sample was represented along the six transects a circles, where the size of the circle was proportional to higher or lower frequencies.

Finally, possible relationships between the grass species suggested by the distribution analysis were tested by means of Yule’s coefficient of association, Q (Zar 1984).

RESULTS

Fifty-two species (including four aliens) were recorded along the transects. Poaceae (grasses) was the best represented family among the 27 families sampled with 7 species (including 3 aliens). Other well represented families were Myrtaceae (6 spp.), Asteraceae (5 spp.) and Fabaceae (5 spp.; Table 2).

Four grass species, two native (Echinolaena inflexa [Poir.] Chase and Diandrostachya chrysostrix [Nees] Jacues Felix) and two alien (Melinis minutiflora Beauv. and Brachiaria decumbens Stapf) surpassed the other species in every phytosociological parameter analyzed (Table 2). The figures for absolute frequency (FA), relative frequency (FR), absolute vigor (VA), relative vigor (VR), and cover (IC) of both M. minutiflora and E. inflexa were much higher than those of other grasses (FA = 33.08 and 38.85%; FR = 23.45 and 27.62%; VA = 67.69 and 59.62%; VR = 28.16 and 24.80%; IC = 100.77 and 98.47, respectively), denoting high density, biomass and cover, and relatively high stratification. The highest stratification, however, occurred with B. decumbens, which had the highest mean number of contacts per point. The indices of importance for M. minutiflora and E. inflexa (IVI = 75.06 and 80.04, respectively) indicated dominance in the community. The results also revealed similar phytosociological patterns between these two species.

Correlation analysis of species distribution showed similar results both when considering all the sampled species or only the four most frequent grass species. Although both qualitative and quantitative analyses have been developed, only the last is presented because it best expresses our study objectives (Fig. 4). A distribution gradient is seen on two axes: one in the direction of M. minutiflora E. inflexa D. chrysostrix and the other where B. decumbens is separated from the other species (Fig. 4b). Comparing the result in Figure 4a to spatial representation for the species (Fig. 5), it shows that M. minutiflora and E. inflexa coexist with similar frequencies. These species also show similar distribution patterns and are regularly distributed along the transects. For D. chrysostrix and B. decumbens, an inverse distribution pattern seems to occur, suggesting a negative relationship between them where D. chrysostrix could be displaced by B. decumbens.

A possible positive relationship between the distributions of M. minutiflora and E. inflexa is indicated by Yule’s coefficient of association, Q = +0.69. However, no relationship is evident be-
<table>
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<th>Species</th>
<th>Family</th>
<th>Life-form</th>
<th>Origin</th>
<th>Ti</th>
<th>Pi</th>
<th>MT</th>
<th>FA (%)</th>
<th>VA (%)</th>
<th>FR (%)</th>
<th>VR (%)</th>
<th>IC</th>
<th>IVI</th>
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<td>0.32</td>
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<td>0.76</td>
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<td>0.16</td>
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<td>0.38</td>
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<td>1</td>
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<td>0.70</td>
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<td>0.82</td>
<td>0.48</td>
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<td>2.12</td>
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<td>1</td>
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<td>0.38</td>
<td>0.38</td>
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<td>1</td>
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<td>0.70</td>
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<td>native</td>
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<td>2</td>
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<td>Origin</td>
<td>Ti</td>
<td>Pi</td>
<td>MT</td>
<td>FA (%)</td>
<td>VA (%)</td>
<td>FR (%)</td>
<td>VR (%)</td>
<td>IC</td>
<td>IVI</td>
</tr>
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<td>-------------</td>
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<td>1</td>
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<td>1.00*</td>
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<td>0.16</td>
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<td>0.38</td>
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</tr>
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<td>1</td>
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<td>0.38</td>
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<td>0.55</td>
<td>0.32</td>
<td>1.54</td>
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<td>2.12</td>
</tr>
<tr>
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<td>native</td>
<td>5</td>
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<td>2.98</td>
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<td>1</td>
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<td>0.76</td>
<td>0.70</td>
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<td>0.27</td>
<td>0.16</td>
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<td>0.70</td>
</tr>
<tr>
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<td>0.27</td>
<td>0.16</td>
<td>0.76</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
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<td>625</td>
<td>141.05</td>
<td>240.26</td>
<td>100.36</td>
<td>100.00</td>
<td>454.99</td>
<td>299.86</td>
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FIGURE 4. Correspondence analysis ordination of herbaceous layer species sampled in the Cerrado de Emas Biological Reserve, considering: a = all sampled species; b = only the four dominant grasses (see text).
FIGURE 5. Schematic representation of the densities of the four dominant grasses sampled along the transects (bigger circles = higher densities).
between *D. chrysotrich* and *B. decumbens* distributions (Q = −0.03).

Figures 4 and 5 also show that although both *M. minuta* and *B. decumbens* are more frequent in the borders, *M. minuta* is also very well established in the center and *B. decumbens* appears in some central points.

**DISCUSSION**

Most of the species sampled, except for *Cuphea calophylla*, had been found in the same area in at least one of two previous floristic studies (Vincent et al. 1992, Batalha et al. in press). Using the same method applied here and sampling 300 points, Vincent et al. (1992) collected (in November 1989) 95 species in the herb/subshrub layer (spp./point ratio = 0.32). Here, only 52 species were found in 260 points (spp./point ratio = 0.20), with 26 species in common (considering only the herb/subshrub component).

Of the 95 herb/subshrub species collected by Vincent et al. (1992) 39 were seasonal + annual (41.1%), confirming the ratio of ca 40 percent for these life-form species in that layer of open cerrados (Mantovani 1987, 1990). Some seasonal species show the epigeous parts only for a few months or even weeks per year (Mantovani 1990) and seasonality is affected also by fire occurring in the area. In this study, the proportion of seasonal + annual species was 26.9 percent (Table 2). Even though it is below the usual 40 percent ratio, seasonality is not enough to explain the much lower species/point ratio found in this study when compared to Vincent et al.’s (1992), suggesting that the low species/point ratio found here indicates a decline in herb/subshrub species richness in the reserve over the five years between Vincent et al.’s study and ours.

When collecting the material, Vincent et al. (1992) and Batalha et al. (in press) avoided a 20–30 m strip along the reserve border (W. Mantovani, pers. comm.). *Brachiaria decumbens* was not found by Vincent et al. (1992) (material collected in November 1989) but was present in Batalha et al.’s (in press) samples (collected in 1994). In their floristic survey of the area, Batalha et al. (in press) recorded 28.18 percent of the herb/subshrub species as invaders. In this study (material collected in April–May 1995), *B. decumbens* was widespread in the reserve, the highest densities in the borders but occurring also in the center of the reserve.

*Melinis minuta* was present in the reserve in 1990 (Vincent et al. 1992). Comparing the values for frequency, vigor, cover, and importance found by Vincent et al. (1992; FA = 2.00%; FR = 1.27%; VA = 3.32%; VR = 1.22%; IC = 5.33; IVI = 3.76) to those of this study (FA = 33.08%; FR = 23.45%; VA = 67.69%; VR = 28.16%; IC = 100.77; IVI = 75.06), a massive increase in abundance for this species from 1990–1995 is evidenced.

These results, together with periodic observations (V. R. Pivello, pers. comm.), indicate a rapid and recent invasion of central parts of the reserve by *B. decumbens*, whereas encroachment was limited to the borders a few years earlier. *M. minuta* had colonized the area long before and now seems to be stabilized, occurring all over the reserve. Several biological attributes have been pointed out as requisite for successful invader species (Crawley 1987, Beering 1995, Pysek et al. 1995); many of them are present in *M. minuta* and *B. decumbens*, such as being heliophytes and hemi-creptophytes, high competitive ability, high seed production, high seed viability rate (Costa & Brandão 1988, Klink 1994), vegetative reproduction, rapid growth, and efficient propagule dispersion (mainly by animals and/or wind).

According to the evidence presented, we suggest that a rapid invasion and expansion by *M. minuta* (earlier) and *B. decumbens* (recently) has been occurring in Cerrado de Emas Biological Reserve, and that these species may have displaced some native herb species. It also appears that *B. decumbens* is more aggressive than *M. Minuta*; where *B. decumbens* is present, it occurs alone in 52.8 percent of the points and together with native species in 33.3 percent of the points, in contrast to 46.5 and 47.7 percent for *M. Minuta*. Moreover, the positive association between *M. minuta* and *Echinolaena inflexa* may indicate that, although they use similar resources, *M. minuta* does not exclude this native species. A more detailed study would be required to confirm these assumptions.

Although an edge-center distribution gradient has been shown, it is not very clear. In the field, however, the abundance of *B. decumbens* is outstanding and this may not have been represented in the analysis due to: (a) small sample size (a larger number of points might have shown this pattern); and (b) *B. decumbens* having greater stratification in height (reaching 70–80 cm) compared to the other species, perhaps giving a false perception of being more plentiful. On the other hand, Pysek et al. (1995) state that taller stature is one of the at-
tributes favorable to efficient invader species, since they can achieve greater efficiency in seed dispersal.

The abundance of alien species in conservation areas has been used to indicate the degree of change in the original communities, because the potential for invasion by many aliens is linked directly to disturbance levels. This seems to apply to African forage grasses, whose establishment success increases in altered ecosystems with disturbed soils (Pivello 1992, Forman 1995, Klink 1996). The great success achieved by the African grasses in this reserve reflects degeneration of the natural communities caused by severe human interference; the reserve is frequently trespassed by locals, who cut off grasses for domestic animals, burn the grass, and deposit waste. Other factors contributing to the degradation of the ecosystem are spatial features of the reserve such as its small size, elongated shape, and the presence of pastures in the neighborhood, associated with the biological attributes of those species cited above.

We believe that the entire reserve now represents an edge being invaded throughout by aliens in a mosaic pattern. The original herb/shrub flora phytosociological parameters must have been highly modified, and the remnants are in a degraded condition. Adopting Nilsson and Grelsson's (1996) definitions, this reserve today represents a high level of fragility.

ACKNOWLEDGMENTS

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