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Life-forms, pollination and seed dispersal syndromes in plant communities on ironstone outcrops, SE Brazil

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RESUMO

(Formas de vida, síndromes de polinização e dispersão de sementes em comunidades vegetais sobre afloramentos ferruginosos, SE do Brasil). Afloramentos rochosos têm um papel importante na diversidade vegetal de ecossistemas montanos. As cangas (afloramentos ferruginosos) estão entre os litotipos menos conhecidos e mais ameaçados do sudeste do Brasil, devido às atividades minerarias. Além da composição de espécies, um aspecto fundamental para promover sua conservação e restauração é o conhecimento das formas de vida, síndromes de polinização e dispersão de sementes dominantes. As análises foram baseadas em listas florísticas publicadas de cangas do sudeste do Brasil. Um total de 353 espécies de angiospermas (70 famílias) foi distribuído entre as duas fisionomias predominantes (áreas abertas e capões de mata) em cangas. Dezesseis famílias foram responsáveis por 70% do total de espécies. Comparado ao espectro normal de Raunkiaer, fanerófitos estiveram super-representados e terófitos sub-representados. Os primeiros foram a forma de vida predominante em capões, enquanto que os hemicriptófitos o foram em áreas abertas. A entomofilia foi a síndrome de polinização dominante em ambos os hábitats. A zoocoria foi dominante em capões e foi última em áreas abertas, onde a anemocoria e autocoria prevaleceram. Considerando que ambas as fisionomias estão sujeitas às mesmas condições climáticas, os resultados corroboram a influência de componentes geoedáficos nos três atributos analisados.

Palavras-chave: Afloramentos rochosos, cangas, conservação, condições geoedáficas, espectro biológico

ABSTRACT

(Life-forms, pollination and seed dispersal syndromes in plant communities on ironstone outcrops, SE Brazil). Rock outcrops play an important role in enhancing plant diversity in montane ecosystems. Ironstone outcrops (cangas) are among the lithotypes less known and most threatened in SE Brazil, due to mining activities. Besides species composition, a key feature to promote their conservation and restoration is the knowledge of the community prevalent life-forms, pollination and seed dispersal syndromes. The analyses were done based on published floristic surveys of cangas in SE Brazil. A total of 353 species of angiosperms (70 families) were assigned to one of the two predominant physiognomies (open areas and forest islands) on ironstone outcrops. Sixteen families responded for 70% of all species. Compared to Raunkiaer's spectrum, phanerophytes were over- and therophytes were under-represented. Phanerophytes were the predominant life-form in forest islands, while hemicryptophytes were outstanding in open areas. Entomophily was the dominant pollination syndrome in both habitats. Zoochory was dominant in forest islands and ranked last in open areas, where anemochory and autochory prevailed. Considering that both forest islands and open areas are subjected to the same climatic conditions, the results corroborate the influence of geoedaphic components in the three traits analysed.

Key words: Biological spectrum, cangas, conservation, geoedaphic conditions, rock outcrops

Introduction

Mountain ranges are key landscape features promoting biological diversity (Burke 2003), due to unique factors related primarily to edapho-climatic variations resulting from altitudinal gradients, allied to the natural topographic discontinuity among mountaintops. Within these, rock outcrops have proven to substantially contribute to regional plant diversity. Over the past two decades the diversity-enhancing role of rock outcrops on mountain environments in tropical and temperate regions has been confirmed for some of the most important rock types, particularly granite, sandstone and ironstone (Barthlott *et al.* 1993; Giulietti *et al.* 1997; Porembski & Barthlott 2000; Kruckberg 2002; Jacobi *et al.* 2007; Jacobi & Carmo 2008a, b).

In tropical regions these rocky environments are in practice xeric islands within matrices of mesic vegetation (Szarzynski 2000), as a consequence of being edaphically-

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controlled. Outcrops are usually characterized by very shallow –if any– soil cover except for depressions and crevices where organic matter is more abundant and humidity long-lasting (Porembski & Barthlott, 2000). These edaphic conditions, allied to altitudinal climatic factors, promote a vast list of environmental stressors, ranging from absence of mechanical support to high daily temperature ranges and strong winds (causing high evapotranspiration and overheated bare substrates), high UV exposure, and low water retention (Safford & Martinelli 2000; Szarzynski 2000).

In Brazilian rock outcrops a considerable amount of information on plant communities is available among the well-studied granitoid inselbergs –gneiss, granite and nepheline-syenite domes (e.g. Meirelles *et al.* 1999; Ribeiro & Medina 2002; Caiafa & Silva 2007) and sandstones outcrops –quartzite and arenite table-mountains (e.g. Alves & Kolbek 1994; Meguro *et al.* 1994; Pirani *et al.* 2003; Conceição & Pirani 2005). Historically, much less is known about the vegetation associated with ironstones outcrops (*cangas*), considering that Brazil is among the few countries where these formations occur. In southeastern Brazil, the "Quadrilátero Ferrífero" (*i.e.*, Iron Quadrangle) is a key economic area recognized as a major worldwide iron producer (IBRAM 2008; 2009), and one of the few in the country to harbor ironstone outcrops. These consist of a crust that covers the main iron ore deposits in the country. Even though they represent the predominant rock outcrop lithotype in the Iron Quadrangle, the flora associated with ironstones was practically ignored until recently, when increasing mining activity raised attention to their high plant diversity and the need for their protection (Jacobi *et al.* 2007, 2008; Jacobi & Carmo 2008b).

Although scanty, floristic surveys have already shown that ironstone outcrops contribute substantially to plant diversity in the Iron Quadrangle. Moreover, the species composition differs significantly from that of the surrounding matrix, which falls within the domain of the two Brazilian hotspots, Cerrado and Atlantic Forest (Jacobi & Carmo 2008a). Considering that cangas share the same environmental stresses and disjoint distribution of other rock outcrop types, but that they are subjected to immediate degradation threats and large habitat loss, it is important to broaden our knowledge of their associated plant community structure and dynamics, of which life-forms and dispersal strategies are respectively key features. Therefore, a further step for their conservation and restoration is to determine which life forms are prevalent in these environments, and which strategies for pollination and seed dispersal are most successful. Our work was directed by three questions: (1) What is the floristic biological spectrum of ironstone-outcrop plant communities? (2) What habitat conditions does this biological spectrum reflect? (3) Which pollination and seed dispersal syndromes occur and in what proportion? With this in mind, the aims of this study were to characterize and discuss the life-forms, pollination and seed dispersal syndromes in plant communities of the two major ironstone outcrop physiognomies occurring in the Iron Quadrangle.

Material and methods

Ironstone outcrop vegetation data

The Iron Quadrangle (IQ), with an area of approximately 7200 km^2, is located in southeastern Brazil. It is the south end portion of the Espinhaço Range, which runs N-S and has a maximum altitude of *ca*. 2072m. This mountain range, with an estimated number of 4000 plant species, is considered one of the world centers of plant diversity (Giulietti *et al.* 1997). The climate is tropical sub-humid and the IQ region, in spite of a mean annual precipitation of 1500-1900 mm, may be subjected to water deficit of five to seven months (April-October) during the winter (Nimer & Brandão 1989). Temperatures close to 70°C measured above patches of bare rock are not uncommon (F. F. Carmo, pers. obs.).

Our analysis of life forms and syndromes was based on the three current publications which have dealt with floristic surveys of ironstone outcrops (known as *cangas*) in SE Brazil for at least one year: Jacobi *et al.* (2007), Viana & Lombardi (2007) and Mourão & Stehmann (2007). All three studies were performed within the Iron Quadrangle (Fig. 1). The first was a study of ironstone outcrop vegetation in Serra do Curral (20°03'33" S – 44°00'34" W, 1460 m asl) and the southern sector of Serra da Moeda (20°20'06" S – 43°56'16" W, 1560 m asl) encompassing 45 ha, which rendered a list of 234 species of vascular plants (Jacobi *et al.* 2007). The second was undertaken in the northern sector of Serra da Moeda (20º05'35" S – 43º59'01" W, 900-1426 m asl) and complemented with herbarium specimens, totaling 246 species of angiosperms in 75 ha (Viana & Lombardi 2007). The last surveyed two sites within Serra do Tamanduá (19º53'08" S – 43º26'11" W, 845m asl; 19º51'06" S – 43º22'35" W, 1063m asl), and found 117 species of angiosperms in 35 ha (Mourão & Stehmann 2007).

Voucher specimens are cited in two of the published works (Mourão & Stehmann 2007; Viana & Lombardi 2007) and those of the species listed in Jacobi *et al.* (2007) are deposited in the same institution as the first two, the herbarium of the Federal University of Minas Gerais (BHCB). In the final combined list, undetermined species (64 spp.), Pteridophytes *sensu lato* (12 spp.), and species common to the four sites were removed. Life-forms and syndromes of each species were assigned by examining voucher specimens, through extensive use of literature which included community-level studies (e.g. Buzato *et al.* 2000; Griz & Machado 2001; Batalha & Martins 2002; Freitas & Sazima 2006; Kinoshita *et al.* 2006; Martins & Batalha 2006; Conceição *et al.* 2007), and from direct field observations, particularly those of Jacobi *et al.* (2007).

Although an extensive array of habitat types occur on ironstone outcrops (Jacobi *et al.* 2007) these were grouped in

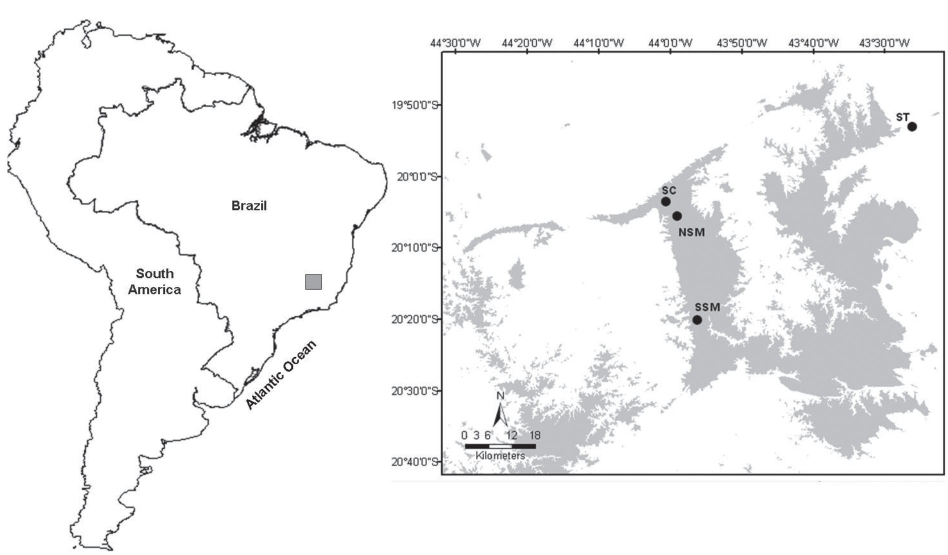

Figure 1. Location of the Iron Quadrangle, SE Brazil (grey rectangle). In detail: Iron Quadrangle region with land above 1000 m shown in grey. SC = Serra do Curral; SSM = Serra da Moeda southern sector; NSM = Serra da Moeda northern sector; ST = Serra do Tamanduá.

only two major vegetation physiognomies for analysis: open herbaceous-shrub vegetation and low forest-shrub islands, following Viana & Lombardi (2007). Open herbaceous-shrub vegetation (hereafter open vegetation or open areas) is the most characteristic of rupicolous communities, and plants grow over bare substrate or colonize small crevices (Fig. 2); water may be scarce even during the rainy season due to the thin layer of soil, so limiting nutrients and water stress are common (Vincent & Meguro 2008). Epilithic species, dwarf shrubs, branched and prostrate forms, and a variety of herbs dominate (Jacobi *et al.*, 2007), and it is in this habitat that adaptations typical of xeric environments, such as sclerophylly and rehydration (notably *Trilepis lhotzkiana* Nees and genus *Vellozia* Vand.), are most commonly found. Patches of low forest-shrub vegetation (hereafter forest islands) thrive only in depressions, large crevices, and other structures which allow organic matter to accumulate, so plants have apparently less water and nutrient restrictions, forming thick patches of associated treelets, epiphytes, and lianas. Although there is a small overlap (<10%) in species occurring in both habitats, we assigned each to its most frequent habitat (Appendix).

Life-forms

The normal biological spectrum, or phyto-climatic spectrum, proposed by Raunkiaer was compared to the frequency of life-forms of the whole outcrop community, as well as to each of the two main vegetation physiognomies separately. This spectrum acts as a null model and ratio deviations from it are used to provide an indication of whether a habitat is subjected to an unfavourable season (Batalha & Martins 2002), such as a dry period, in this context. The comparison of both physiognomies followed Raunkiaer´s classification modified by Mueller-Dombois and Ellenberg (1974), to include lianas, epiphytes, and hemiparasites.

Syndromes

Each species was assigned to its primary pollination or seed dispersal syndrome. Pollination syndromes (Faegri & van der Pijl 1979) considered were by wind, bees, flies, moths and butterflies, insects (all other groups), birds, bats, and ambophily (pollination by both wind and insects). The primary seed dispersal syndromes were grouped in three categories (van der Pijl 1982; Howe & Smallwood 1982): anemochory, autochory and zoochory. Within these, autochory included both ballistic and gravity-assisted dispersal, while zoochory included epizoochory and endozoochory (external and internal passive carrying of diaspores), as well as synzoochory (deliberate transport of diaspores, represented by two species of Loranthaceae and one of Santalaceae).

Frequencies of life-forms between the two main vegetation physiognomies, and with the Raunkiaer proportions were compared with a G-test (goodness-of-fit, based on maximum-likelihood ratios) available in software BioEstat 3.0 (Ayres *et al.* 2003). No attempts were made to quantify either syndromes or life forms by species abundance (cover or density), since the analyses were based on floristic checklists.

Results and discussion

The combination of all the checklists of ironstone outcrops totaled 353 species of angiosperms, belonging to 70 families, in approximately 155 ha. Less than 4% of the spe-

Figure 2. View of ironstone outcrop with open herbaceous-shrub vegetation.

cies occurred in all four sites, and 64% in only one outcrop (Appendix). The open vegetation physiognomy dominated in terms of area (*ca.* 70%) and 248 species were associated with it, while 105 species occurred in forest islands. Herbs dominated with almost 37% of all species, followed by shrubs and sub-shrubs. As expected, the percentage of trees and lianas was low, and mainly associated with forest islands.

In open areas the great majority of species were nanophanerophytes (< 2 m tall), some exceptions being *Pseudobrickellia brasiliensis* (Asteraceae), *Agarista oleifolia* (Ericaceae), *Hyptis lippioides* (Lamiaceae), *Cinnamomum quadrangulum* (Lauraceae), *Solanum lycocarpum* (Solanaceae), and *Lippia hermannioides* (Verbenaceae), none attaining 5 m, and therefore classified as microphanerophytes (2-8 m). The latter category composed the bulk of forest-island species, and the presence of a few species under 2 m seems to be related to patches of poor microenvironmental conditions rather than to life-form.

Six species are allegedly endemic to ironstone outcrops in the IQ (Viana 2008), and all occurred exclusively in open areas: *Arthrocereus glaziovii* (Cactaceae), *Dyckia consimilis* and *Vriesea minarum* (Bromeliaceae), *Mimosa calodendron* (Fabaceae), *Sinningia rupicola* (Gesneriaceae), and *Oncidium gracile* (Orchidaceae). All are chamaephytes except for *S. rupicola* (cryptophyte) and *M. calodendron* (phanerophyte). Bromeliads and *S. rupicola* are bird-pollinated, whereas the other three are entomophilous. Seed dispersal is by wind except in *A. glaziovii* (zoochory) and *M. calodendron* (barochory).

Sixteen families accounted for 70% (n = 248) of all species, therefore influencing the outcome of life-form and syndrome proportions (Table 1). It is common to find prevalence of a particular dispersal mode or life-form within a family or genus because of the phylogenetic correlation, and this provides additional information on strategies that are most successful in different environments (Arbeláez & Parrado-Rosselli 2005). Of these families, ten were represented in the list by predominantly (> 50%) or exclusively phanerophytes. The three dispersal modes were evenly distributed among the 16 families, but wind-dispersal accounted for 42% of the species, a reflection of the high species richness of Asteraceae, Orchidaceae, and Apocynaceae, whereas autochory ranked last with 24%. The six families which are primarily animal-dispersed occur mainly in forest islands. Regarding pollination syndromes, entomophily prevailed in a broad sense, ranging from non-specialized

Table 1. Characteristic life forms and syndromes of the 16 more speciose families in ironstone outcrops from the Iron Quadrangle, SE Brazil. Percentages in brackets indicate the proportion of that particular main life form or syndrome of the total species found on the outcrops. Life forms: Cham = chamaephyte, Hem = hemicryptophyte, Phan = phanerophyte. Dispersal syndromes: Anemo = anemochory, Auto = autochory, Zoo = zoochory. Pollination syndromes: Anemo = anemophily, Entomo = entomophily, Melitto = melittophily, Ornitho = ornithophily.

Family	Number of species	Main Life Form	Number of species (%)	Main Dispersal Syndrome	Number of species (%)	Main Pollination Syndrome	Number of species (%)
Asteraceae	41	Phan	23 (53.6)	Anemo	35 (85.3)	Entomo	41 (100)
Poaceae	25	Hemi	22 (88)	Zoo	9 (36)	Anemo	25 (100)
Orchidaceae	23	Cham	16 (69.5)	Anemo	23 (100)	Entomo	23 (100)
Myrtaceae	21	Phan	21 (100)	Zoo	21 (100)	Melitto	21 (100)
Solanaceae	17	Phan	11 (64.7)	Zoo	15 (88.2)	Melitto	16 (94.1)
Fabaceae	17	Phan	10 (58.8)	Auto	15 (88.2)	Melitto	9 (52.9)
Melastomataceae	16	Phan	9 (56.2)	Zoo	7 (43.7)	Melitto	16 (100)
Cyperaceae	13	Hemi	12 (92.3)	Auto	13 (100)	Anemo	13 (100)
Apocynaceae	13	Liana	12 (92.3)	Anemo	13 (100)	Entomo	13 (100)
Rubiaceae	12	Phan	6 (50)	Zoo	10 (83.3)	Entomo	12 (100)
Bromeliaceae	11	Cham	9 (81.8)	Anemo	6 (54.5)	Ornitho	10 (90.9)
Verbenaceae	9	Phan	7 (77.7)	Auto	6 (66.6)	Entomo	6 (66.6)
Velloziaceae	8	Cham	7 (87.5)	Auto	8 (100)	Ornitho	5 (62.5)
Malpighiaceae	8	Phan	7 (87.5)	Anemo	7 (87.5)	Melitto	8 (100)
Lamiaceae	7	Phan	7 (100)	Zoo	5 (71.4)	Entomo	7 (100)
Euphorbiaceae	7	Phan	6 (87.7)	Auto	6 (87.7)	Entomo	7 (100)

flowers pollinated by several insect families, such as Asteraceae, Orchidaceae, and Verbenaceae, to those exclusively melittophilous (bee-pollinated), frequently bearing special anther openings (*e.g.*, Melastomataceae and *Solanum*) or offering uncommon resources (*e.g.*, oil in Malpighiaceae), which demand specific foraging skills or body structures. Grasses and sedges were exclusively wind-pollinated.

Overall, considering open areas and forest islands together, phanerophytes (mostly semideciduous) predominated (44%), followed by hemicryptophytes (26%) and chamaephytes (15%). The contribution of each physiognomy to this proportion (Fig. 3), however, was significantly different. In forest islands, phanerophytes (microphanerophytes) predominated (71%) and all other life forms were poorly represented except for lianas (12%). The most representative genera with phanerophytic species were *Solanum*, *Myrcia*, *Eugenia*, *Eremanthus*, *Miconia*, *Vismia*, *Guapira*, and *Myrsine.* On the other hand, in open areas, phanerophytes (mostly sclerophyllous nanophanerophytes) and graminoid hemicryptophytes had similar representation of approximately one-third, followed by chamaephytes (19%). In this physiognomy the most representative genera with phanerophytic species were *Baccharis*, *Mimosa*, and *Lippia*, whereas *Panicum*, *Paspalum* and *Rhynchospora* were important hemicryptophytes.

The floristic biological spectrum of the entire canga vegetation (species from both open vegetation and forest-island physiognomies) is significantly different from Raunkiaer's (or normal) biological spectrum (G-test = 12.19, d.f. = 4, p = 0.016), with phanerophytes over- and therophytes under-represented, respectively. The scarcity of annual plants has already been noted for inselbergs from southeastern Brazil (Safford & Martinelli 2000), as well as cerrado vegetation compared to other savannas (Batalha & Martins 2002). When analyzed separately, the deviation of forest islands from the normal spectrum is noticeable (G-test = 47.98, d.f. = 4, p < 0.0001), the highest weight in the deviation corresponded to two life-forms: phanerophytes, with almost double the proportion of the normal spectrum (46%), and therophytes, with no species compared to the normal 13%. Comparatively, open areas did not contribute as extensively as forest islands to the deviation observed in the overall result (G-test = 12.28, d.f. = 4, p = 0.018). In agreement, the difference between life-form spectra was significant also between both physiognomies, either when only the five typical Raunkiaer categories were used (G-Test = 53.45, d.f. = 4, p < 0.0001) or when were they were redistributed to single out epiphytes, parasites, and lianas (G-Test = 56.31, d.f. = 7, p < 0.0001).

Life-forms reflect the predominant environmental conditions to which plant communities are subjected (Mueller-Dombois & Ellenberg 1974; Mera *et al.* 1999). Raunkiaer´s spectrum is useful to associate deviations of specific spectra to more favourable or unfavorable phytoclimatic conditions (Cain 1950). Although its use in tropical communities has been criticized because the principle that the level of protection of meristems/buds are related to low winter temperatures would not be relevant in the tropics (Sarmiento & Monasterio 1983; Rizzini 1997), rainfall regime stands as the unfavorable climatic factor that applies to tropical ecosystems. However, the comparison of open areas with forest islands, in practice subjected to the same climatic conditions, showed an important influence of the substrate in edaphic and microclimatic conditions. The same amount of rain falling in both habitats is retained for longer periods in forest islands, supported by a deeper litter layer, and allowing the establishment of treelets in detriment to herbs. Ironstone outcrops are not compact structures, and it is common to find cavities of different sizes underneath what appears to be a hard crust (Simmons 1963; Jacobi *et al.* 2007), where nutrient and humidity conditions create a milder environment than on the surface. Roots may reach these cavities through fissures, and may therefore find a more suitable refuge for their development. Thus, geoedaphic variables seem to be a key component determining life-form spectra in these plant communities.

The use of syndromes to determine the effective dispersal and pollination vector has also been subjected to criticism, since this analysis usually excludes potential dispersers and pollinators which may be of importance in certain situations (Howe & Smallwood 1982; Hingston & McQuillan 2000). Particularly in the case of pollination, associating each plant species to only one pollination syndrome must have masked the well-known generalist ability of floral visitors (Waser *et al.* 1996). Similarly, Griz & Machado (2001) also alerted to generalizations regarding dispersal of individual species, although they advocate this approach at the community level. Since this study did not analyze syndromes by predominance of individuals, our analysis cannot evaluate the success of each syndrome or species in terms of density or biomass. Nevertheless, they are still used as organizing tools, because they provide general answers regarding major or successful dispersal strategies at the community level.

Entomophily was the primary syndrome of 77% of all species in Table 1. Although it was predominant in both habitats, it accounted for more than 91% in forest islands, and only 70% in open areas (Fig. 4), where the second and third most representative categories were wind (16%) and hummingbird (13%) pollination. Among those pollinated by insects, melittophily prevailed in both physiognomies, and most of the outstanding bee-pollinated families were also common to both: Asteraceae, Fabaceae, Melastomataceae, Myrtaceae, and Solanaceae. In open areas, Convolvulaceae, Euphorbiaceae, Orchidaceae, and Velloziaceae were also important bee-pollinated families.

Syndromes of pollination by moths and butterflies were more frequent in forest islands, and cantarophily (beetle-pollination) occurred exclusively in these habitats, represented by two species of *Guatteria* Ruiz & Pav. Fly-pollination prevailed in open areas, associated with *Acianthera* Scheidw., *Hydrocotyle* L. and *Aristolochia* L. The majority (78%) of bird-pollinated species occurred in open areas, highlighting Bromeliaceae, Gesneriaceae, and Velloziaceae as the most frequent. In the entire community only four species were either ambophilous (*Peperomia* Ruiz & Pav.) or bat pollinated (*Bauhinia rufa* (Bong.) Steud. and *Lafoensia pacari* A.St.-Hil.).

Animal-dispersal of diaspores, primarily by frugivory, grouped 37% of all species in Table 1, followed closely by anemochory (33%) and autochory, with 30%. Comparing physiognomies, zoochory (mainly ornithochory) was predominant in forest islands (82%), but ranked last in open areas (18%), where autochory and anemochory (both with 41%) dominated (Fig. 5). Zoochory in forest islands was predominant in Myrtaceae, Solanaceae, Nyctaginaceae, Melastomataceae, and Rubiaceae. In open habitats the zoochoric families with more species were Solanaceae, Melastomataceae, and Bromeliaceae. The proportion of zoochory seems to be related to substrate properties, which influence the development of the root system and the ability to retain and store water. Among these outcrops, zoochory in forest islands, mainly in the form of dispersal by birds, reached a value that is more characteristic of tropical rainforests or at least ecosystems with a short dry season (Howe & Smallwood 1982; Safford & Martinelli, 2000).

Families with a higher number of wind-dispersed species in open habitats were Asteraceae, Orchidaceae, Apocynaceae, Poaceae, and Malpighiaceae and, in forest islands, Asteraceae, Bromeliaceae, Bignoniaceae, Orchidaceae, and Sapindaceae. Autochorous families in open habitats with more species were Poaceae, Cyperaceae, Velloziaceae, Verbenaceae, Melastomataceae (all of these predominantly gravity-assisted), Fabaceae, and Euphorbiaceae (the last two with some representatives of ballistic dispersal). In forest islands the families with more self-dispersed species were Fabaceae and Acanthaceae.

Animal dispersal of both seeds and pollen was found in 36% of the species, and 51% showed syndromes that indicate animal vectors for one of them, highlighting the importance of mutualistic relations in the maintenance of population processes. Only 13% of species, on the other hand, showed both abiotic pollination and seed dispersal. Of the species that presented biotic syndromes of both pollination and dispersal, 71% belonged to forest islands. On the other hand, 95% of the species that exploit abiotic pollination and dispersal vectors belonged to herbaceous vegetation. As expected, anemochorous species predominated in the open environment, but there was a surprisingly high percentage of zoophilous species in this physiognomy, particularly insect-pollinated.

Some syndromes were strongly associated with certain life forms, such as bat pollination with phanerophytes, entomophily with hemiparasites, lianas and phanerophytes, and anemochory with therophytes and hemicryptophytes. Considering the clear contrast between the biological spectra of open areas and forest islands, we can observe an association between habitats, life forms and pollination syndromes, a phenomenon corroborated by Ramírez (2004) in the Venezuelan savannas. In the entire community, bat-pollination was rare and observed only in phanerophytes. Ambophily occurred in chamaephytes (2%), and hemicryptophytes (1%). Wind pollination syndrome was observed in therophytes (59%), hemicryptophytes (38%), and less so in chamaephytes (2%). Bird-pollination was more frequent among cryptophytes (45%) and chamaephytes (27%).

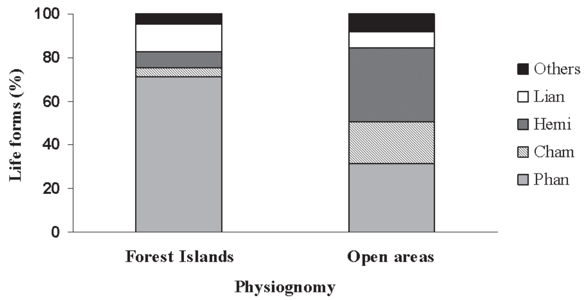

Figure 3. Life-form proportions of the two main physiognomies on ironstone outcrops from the Iron Quadrangle, SE Brazil. For abbreviations see Table 1.

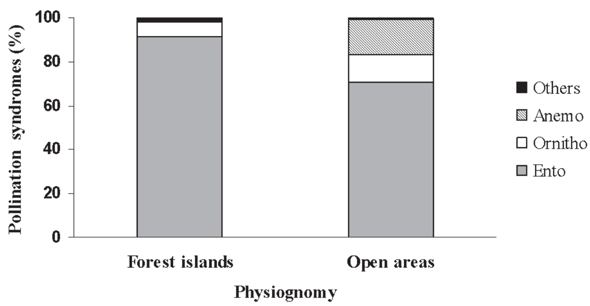

Figure 4. Pollination syndrome proportions of the two main physiognomies on ironstone outcrops from the Iron Quadrangle, SE Brazil. For abbreviations see Table 1.

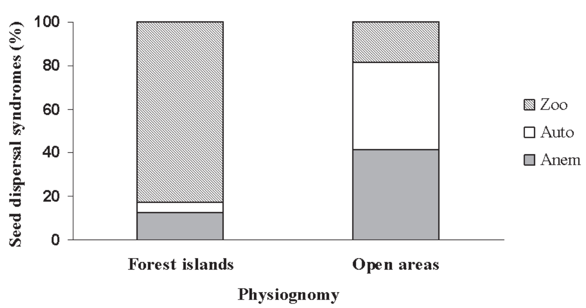

Figure 5. Seed dispersal syndrome proportions of the main two main physiognomies on ironstone outcrops from the Iron Quadrangle, SE Brazil. For abbreviations see Table 1.

Insect-pollination was the only syndrome occurring in all life forms, including hemiparasites (100%), lianas (93%) and phanerophytes (92%). Overall, zoochory was not observed in cryptophytes, but occurred in hemiparasites (Loranthaceae and Santalaceae), most phanerophytes (59%), and lianas (37%). Wind-dispersal was prevalent in therophytes (75%), cryptophytes (73%), and lianas (53%). Autochory was more frequent among hemicryptophytes (47%), chamaephytes (35%) and cryptophytes (27%).

In spite of being subjected to the same climate, the life-form spectra and syndromes in forest islands and open herbaceous vegetation are considerably different, and overall they respond to both habit (e.g. tree-shrubs vs. herbs) and physiognomy (forest islands vs. herbs-shrubs), which in turn are the product of geoedaphic conditions and their relationship with other environmental variables. Forest islands on ironstone outcrops had profiles poorly related with outcrop ecosystems, recognized as open systems; rather, they showed closer affinity with the surrounding Cerrado and Atlantic Forest matrix physiognomies, underlining the milder microclimatic conditions to which they are subjected. One aspect in common is that species in both physiognomies appear to be highly dependent on animals, especially pollinators, for their continued existence, and it is possible that this group might decline in abundance or diversity in a near future, considering the anthropic pressures to which cangas are subjected. How this might affect the structure and dynamics of these ecosystems is a topic that demands future studies, if possible integrating quantitative analyses of the plant communities, their vectors and substrate characteristics.

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Appendix. Occurrence of the 353 angiosperm species in the four sites studied by Jacobi *et al.* (2007), Mourão & Stehmann (2007), and Viana & Lombardi (2007). LF: life-forms; Ch: chamaephyte; Cr: cryptophyte; Ep: epiphyte; He: hemicryptophyte; Hp: hemiparasite; Li: liana/vine; Ph: phanerophyte; Te: therophyte; PS: pollination syndromes; Am: Ambophily; An: anemophily; Chi: Chiropterophily; En: entomophily; Or: ornitophily; DS: dispersal syndromes; Ane: anemochory; Au: autochory; Zo: zoochory; N: number of occurrences; Phy: predominant physiognomy; FI: forest islands; OA: open areas. * = endemic to ironstone outcrops (Viana 2008).

Species	LF	PS	DS	N	Phy
ACANTHACEAE					
Justicia riparia Kameyana	Ph	Or	Au	3	FI
Ruellia villosa Lindau *ex* Glaz.	Ph	Or	Au	2	OA
Staurogyne minarum Kuntze	Ch	Or	Au	1	FI
ALSTROEMERIACEAE					
Alstroemeria plantaginea Mart.	Cr	Or	Au	2	OA
AMARYLLIDACEAE					
Habranthus irwinianus Ravenna	Cr	Or	Au	3	OA
Hippeastrum glaucescens Mart.	Cr	Or	Au	1	OA
ANACARDIACEAE					
Tapirira obtusa (Benth.) D.J. Mitch.	Ph	En	Zo	1	FI
ANNONACEAE					
Guatteria sellowiana Schltdl.	Ph	En	Zo	2	FI
Guatteria villosissima A.St.-Hil.	Ph	En	Zo	2	FI
APIACEAE					
Eryngium eurycephalum Malme	Hm	En	Au	1	OA
Eryngium juncifolium (Urb.) Mathias & Constance	Hm	En	Au	1	OA
APOCYNACEAE					
Asclepias candida Vell.	Li	En	Ane	1	FI
Blepharodon nitidum (Vell.) J. F. Macbr.	Li	En	Ane	1	OA
Ditassa aequicymosa E. Fourn.	Li	En	Ane	1	OA
Ditassa linearis Mart.	Li	En	Ane	3	OA
Ditassa mucronata Mart.	Li	En	Ane	3	OA
Forsteronia velloziana (A. DC.) Woodson	Li	En	Ane	1	OA
Hemipogon carassensis (Malme) Rapini	Li	En	Ane	1	OA
Mandevilla moricandiana (A. DC.) Woodson	Li	En	Ane	1	FI
Mandevilla scabra (Roem. & Schult.) K. Schum.	Li	En	Ane	1	OA
Mandevilla tenuifolia (J.C.Mikan) R.E.Woodson	Cr	En	Ane	1	OA
Matelea pedalis (E. Fourn) Fontella & E. A. Shwarz	Li	En	Ane	1	OA
Oxypetalum appendiculatum Mart.	Li	En	Ane	1	OA
Oxypetalum strictum Mart.	Li	En	Ane	1	OA
AQUIFOLIACEAE					
Ilex cf. *dumosa* Reissek	Ph	En	Zo	1	OA
ARACEAE					
Anthurium megapetiolatum E.G.Gonç.	Ch	En	Zo	1	FI
Anthurium minarum Sakuragui & Mayo	Ch	En	Zo	2	OA
Anthurium scandens (Aubl.) Engl.	Ep	En	Zo	2	FI
ARALIACEAE					
Hydrocotyle quinqueloba Ruiz & Pav.	Te	En	Au	1	OA
Schefflera vinosa (Cham. & Schltdl.) Frodin & Fiaschi	Ph	En	Zo	1	FI
ARISTOLOCHIACEAE					
Aristolochia smilacina Duch.	Ch	En	Ane	1	OA

Continues

Appendix. Continuation

Species	LF	PS	DS	N	Phy
ASTERACEAE					
Achyrocline chionaea (DC.)Deble & Marchiori	Te	En	Ane	2	OA
Ageratum fastigiatum (Gardner) R. M. King & H. Rob.	Ph	En	Au	3	OA
Ageratum myriadenium R.M.	Ph	En	Au	1	OA
Baccharis erigeroides DC.	Ph	En	Ane	1	OA
Baccharis ramosissima Gardner	Ph	En	Ane	1	OA
Baccharis reticularia DC.	Ph	En	Ane	4	OA
Baccharis rufescens Spreng.	Ph	En	Ane	1	OA
Baccharis serrulata Pers.	Ph	En	Ane	3	OA
Bidens brasiliensis Scherff	Li	En	Zo	1	FI
Bidens segetum Mart. *ex* Colla	Li	En	Zo	1	FI
Chaptalia cf. *martii* (Baker) Zardini	Hm	En	Ane	1	OA
Chaptalia integerrima (Vell.) Burkart	Hm	En	Ane	1	OA
Chrysolaena herbacea (Vell.) H. Rob.	Hm	En	Ane	1	OA
Cyrtocymura scorpioides (Lam.) H. Rob.	Ph	En	Ane	1	OA
Dasyanthina palustris (Gardner) H.Rob.	Hm	En	Ane	1	OA
Dasyphyllum candolleanum (Gardner) Cabrera.	Ph	En	Ane	4	OA
Eremanthus elaegnus Sch. Bip.	Ph	En	Ane	1	FI
Eremanthus erythropappus (DC.) MacLeish	Ph	En	Ane	3	FI
Eremanthus glomerulatus Less.	Ph	En	Ane	1	FI
Eremanthus incanus (Less.) Less.	Ph	En	Ane	2	FI
Eupatorium multiflosculosum DC.	Hm	En	Ane	1	OA
Gochnatia polymorpha (Less.) Cabrera	Ph	En	Ane	1	OA
Heterocondylus alatus (Vell.) R.M.King & H.Rob	Hm	En	Ane	1	OA
Hololepis pedunculata DC.	Ph	En	Ane	2	OA
Koanophyllon adamantium (Gardner) R.M. King & H. Rob.	Ph	En	Ane	1	OA
Lepidaploa cotoneaster (Willd. *ex* Spreng.) H.Rob.	Hm	En	Ane	1	OA
Lessingianthus desertorum (Mart. *ex* DC.) H. Rob.	Hm	En	Ane	1	OA
Lychnophora cf. *reticularia* Gardner	Ph	En	Ane	1	OA
Lychnophora pinaster Mart.	Ph	En	Ane	4	OA
Mikania cf. *microphylla* Sch. Bip. *ex* Baker	Ph	En	Ane	1	OA
Piptocarpha macropoda (DC.) Baker	Ph	En	Ane	1	OA
Pseudobrickellia brasiliensis (Spreng.) R.M. King & H. Rob.	Ph	En	Ane	2	OA
Senecio adamantinus Bang.	Hm	En	Ane	1	OA
Senecio pohlii Sch. Bip. *ex* Baker	Hm	En	Ane	1	OA
Stenocephalum tragiaefolium (DC.) Sch. Bip.	Hm	En	Ane	1	OA
Stevia urticifolia Thunb.	Hm	En	Ane	1	OA
Symphyopappus brasiliensis (Gardner) R.M. King & H. Rob.	Ph	En	Ane	3	OA
Trichogoniopsis adenantha (DC.) R.M King & H. Rob.	Hm	En	Ane	1	OA
Trixis vauthieri DC.	Ph	En	Ane	3	OA
Vernonia buddleiifolia Mart. *ex* DC.	Hm	En	Au	1	OA
Viguiera kunthiana Gardner	Hm	En	Au	1	OA
BEGONIACEAE					
Begonia rufa Thunb.	Ph	En	Au	2	OA

Continues

Appendix. Continuation

Species	LF	PS	DS	N	Phy
BIGNONIACEAE					
Anemopaegma arvense (Vell.) Stellfeld *ex* de Souza	Hm	En	Ane	1	FI
Pyrostegia venusta (Ker Gawl.) Miers	Li	Or	Ane	3	FI
BORAGINACEAE					
Cordia curassavica (Jacq.) Roem. & Schult.	Ph	En	Zo	1	OA
BROMELIACEAE					
Aechemea bromeliifolia Baker *ex* Beth. & Hook. f.	Ch	Or	Zo	3	FI
Aechmea nudicaulis Griseb.	Ch	Or	Zo	1	OA
Billbergia elegans Mart. *ex* Schult. f.	Ch	Or	Zo	1	FI
Billbergia minarum L.B.Sm.	Ch	Or	Zo	2	FI
Cryptanthus schwackeanus Mez	Ch	En	Zo	2	OA
Dickia rariflora Schultes f.	Ch	Or	Ane	1	OA
Dyckia cf. *simulans* L.B.Sm.	Ch	Or	Ane	2	OA*
Dyckia consimilis Mez	Ch	Or	Ane	1	OA
Tillandsia geminiflora Brongn.	Ep	Or	Ane	1	FI
Tillandsia recurvata (L.) L.	Ep	Or	Ane	1	FI
Vriesea minarum L.B. Sm.	Ch	Or	Ane	3	OA*
CACTACEAE					
Arthrocereus glaziovii (Schumann.) N.P. Taylor & D.C. Zappi	Ch	En	Zo	3	OA*
CAMPANULACEAE					
Lobelia camporum Pohl	Hm	En	Ane	1	OA
CELASTRACEAE					
Maytenus gonoclada Mart.	Ph	En	Zo	2	FI
CLUSIACEAE					
Clusia arrudae Planch. & Triana *ex* Engl.	Ph	En	Zo	2	FI
Kielmeyera regalis Saddi	Ph	En	Ane	1	OA
COMMELINACEAE					
Commelina erecta L.	Hm	En	Zo	4	FI
Dichorisandra hexandra (Aubl.) Standl.	Hm	En	Zo	2	FI
CONVOLVULACEAE					
Evolvulus aurigenius Mart.	Hm	En	Au	1	OA
Evolvulus filipes Mart.	Hm	En	Au	3	OA
Evolvulus macroblepharis Mart.	Hm	En	Au	1	OA
Ipomoea polymorpha Riedel	Hm	En	Ane	1	OA
Jacquemontia prostrata Choisy	Hm	En	Ane	1	OA
CUNONIACEAE					
Lamanonia ternata Vell.	Ph	En	Ane	1	FI
CYPERACEAE					
Bulbostylis fimbriata (Nees) C. B. Clarke	Hm	An	Au	4	OA
Cyperus aggregatus (Willd.) Endl.	Hm	An	Au	2	OA
Cyperus hermaphroditus (Jacq.) Standl.	Hm	An	Au	1	OA
Cyperus subcastaneus D. A. Simpson	Hm	An	Au	1	OA
Eleocharis minima Kunth	Hm	An	Au	1	OA
Lagenocarpus rigidus Nees	Hm	An	Au	2	OA

Continues

Appendix. Continuation

Species	LF	PS	DS	N	Phy
Rhynchospora consanguinea Boeckeler	Hm	An	Au	1	OA
Rhynchospora exaltata Kunth	Hm	An	Au	3	OA
Rhynchospora setigera Boeckeler	Hm	An	Au	3	OA
Rhynchospora tenuis Link	Hm	An	Au	2	OA
Scleria acanthocarpa Boeckeler	Hm	An	Au	1	OA
Scleria latifolia Sw.	Hm	An	Au	1	OA
Trilepis lhotzkiana Nees *ex* Arn.	Ch	An	Au	4	OA
DIOSCOREACEAE					
Dioscorea debilis Uline	Li	En	Ane	1	OA
ERICACEAE					
Agarista oleifolia G.Don	Ph	Or	Au	1	OA
Agarista coriifolia (Sleumer)W.S.Judd	Ph	Or	Au	1	OA
Gaylussacia brasiliensis Meissn.	Ph	Or	Au	1	OA
ERYTHROXYLACEAE					
Erythroxylum bicolor O. E. Schulz	Ph	En	Zo	1	FI
Erythroxylum gonocladum (Mart.) O.E.Schultz	Ph	En	Zo	1	OA
Erythroxylum pelleterianum A.St.-Hil.	Ph	En	Zo	1	OA
EUPHORBIACEAE					
Alchornea triplinervia (Spreng.) Müll. Arg.	Ph	En	Zo	3	FI
Croton lobatus Forsk.	Ph	En	Au	1	OA
Croton migrans Casar.	Ph	En	Au	2	OA
Croton serratoideus Radcl.-Sm. & Govaerts	Ch	En	Au	1	OA
Sapium haematospermum Müll. Arg.	Ph	En	Au	1	FI
Sebastiania glandulosa (Sw.) Müll. Arg.	Ph	En	Au	4	OA
Sebastiania hispida (Mart.) Pax.	Ph	En	Au	1	OA
FABACEAE					
Abarema obovata (Benth.) Barneby & Grimes	Ph	En	Au	1	FI
Bauhinia rufa (Bong.) Steud.	Ph	Chi	Au	3	OA
Centrosema coriaceum Benth.	Li	En	Au	1	OA
Centrosema vetulum Mart.	Li	En	Au	1	OA
Chamaecrista mucronata (Spreng.) Irwin & Barneby	Ch	En	Au	1	OA
Chamaecrista rotundifolia (Pers.) Greene	Ch	En	Au	1	OA
Chamaecrista secunda (Benth.) H.S	Ch	En	Au	1	OA
Copaifera langsdorffii Desf.	Ph	En	Zo	2	FI
Galactia martii DC.	Li	En	Au	3	OA
Mimosa calodendron Mart. *ex* Benth.	Ph	En	Au	2	OA*
Mimosa dolens Vell.	Ph	En	Au	1	OA
Mimosa neuroloma Benth.	Ph	En	Au	1	OA
Mimosa setistipula Benth.	Ph	En	Au	1	OA
Periandra mediterranea (Vell.) Taub.	Ch	En	Au	3	OA
Senna macranthera (Collad.)H	Ph	En	Au	1	FI
Senna rugosa (G. Don) H. S. Irwin & Barneby	Ph	En	Au	1	FI
Stryphnodendron polyphyllum Mart.	Ph	En	Zo	1	FI
GENTIANACEAE					
Calolisianthus pendulus Gilg.	Hm	Or	Au	1	OA

Continues

Appendix. Continuation

Species	LF	PS	DS	N	Phy
GESNERIACEAE					
Nematanthus strigillosus (Mart.)H.E.Moore	Ch	Or	Zo	1	OA
Paliavana sericiflora Benth.	Hm	Or	Zo	3	OA
Sinningia allagophylla (Mart.) Wiehler	Cr	Or	Ane	2	OA
Sinningia rupicola (Mart.) Wiehler	Cr	Or	Ane	3	OA*
HUMIRIACEAE					
Humiriastrum dentatum (Casar.) Cuatrec.	Ph	En	Zo	1	FI
HYPERICACEAE					
Vismia brasiliensis Choisy	Ph	En	Zo	1	FI
Vismia magnoliifolia Schltdl. & Cham.	Ph	En	Zo	1	FI
Vismia parviflora Cham. & Schltdl.	Ph	En	Zo	1	FI
IRIDACEAE					
Neomarica rupestris (Ravenna) N.S. Chukr	Hm	Or	Au	2	OA
Sisyrinchium vaginatum Spreng.	Hm	En	Au	2	OA
LAMIACEAE					
Aegiphila lhotskiana Cham.	Ph	En	Zo	1	FI
Aegiphila verticillata Vell.	Ph	En	Zo	1	FI
Eriope macrostachya Mart. *ex* Benth.	Ph	En	Au	2	OA
Hyptis lippioides Pohl *ex* Benth.	Ph	En	Au	1	OA
Vitex cymosa Bertero *ex* Spreng.	Ph	En	Zo	1	OA
Vitex polygama Cham.	Ph	En	Zo	1	FI
Vitex sellowiana Cham.	Ph	En	Zo	1	FI
LAURACEAE					
Cinnamomum quadrangulum (Meisn.) Kosterm.	Ph	En	Zo	2	OA
Ocotea pulchella (Nees) Mez	Ph	En	Zo	2	FI
Ocotea tristis (Nees & Mart.) Mez	Ph	En	Zo	3	OA
LOGANIACEAE					
Spigelia schlechtendaliana Mart.	Hm	En	Au	1	OA
LORANTHACEAE					
Struthanthus flexicaulis Mart.	Hp	En	Zo	3	OA
Tripodanthus acutifolius (Ruiz & Pav.) Tiegh.	Hp	En	Zo	2	OA
LYTHRACEAE					
Cuphea ericoides Cham. & Schltdl.	Hm	En	Ane	1	OA
Cuphea thymoides Cham. & Schltd.	Hm	En	Ane	2	OA
Diplusodon cf. *hirsutus* (Cham. & Schltdl.) DC.	Ph	En	Au	1	OA
Diplusodon myrsinitis DC.	Ph	En	Au	1	OA
Lafoensia pacari A. St. Hil	Ph	Chi	Ane	1	FI
MALPIGHIACEAE					
Banisteriopsis angustifolia (A.Juss.) B.Gates	Ph	En	Ane	1	OA
Banisteriopsis malifolia (Nees & Mart.) B.	Ph	En	Ane	1	FI
Byrsonima variabilis A.Juss.	Ph	En	Zo	3	OA
Heteropteris campestris A.Juss.	Ph	En	Ane	1	OA
Heteropterys umbellata A. Juss.	Ph	En	Ane	1	OA
Peixotoa tomentosa A. Juss.	Ch	En	Ane	3	OA

Continues

Appendix. Continuation

Species	LF	PS	DS	N	Phy
Tetrapteris acutifolia Cav.	Ph	En	Ane	1	OA
Tetrapterys microphylla (A. Juss.) Nied.	Ph	En	Ane	1	OA
MALVACEAE					
Pavonia guerikeana R.E.Fr.	Ph	Or	Zo	1	OA
Pavonia viscosa A.St.-Hil.	Ph	Or	Zo	1	OA
Sida glaziovii K. Schum.	Te	En	Zo	1	OA
Waltheria indica L.	Hm	En	Ane	1	OA
MELASTOMATACEAE					
Cambessedesia corymbosa DC.	Hm	En	Ane	1	OA
Cambessedesia hilariana (Kunth) DC.	Hm	En	Ane	2	OA
Lavoisiera cf. *imbricata* DC.	Hm	En	Ane	1	OA
Leandra aff. *aurea* (Cham.) Cogn.	Ph	En	Zo	1	OA
Leandra aff. *cancellata* Cogn.	Ph	En	Zo	1	OA
Leandra australis (Cham.) Cogn.	Ph	En	Zo	3	OA
Marcetia taxifolia DC.	Hm	En	Au	1	OA
Miconia chartacea Triana	Ph	En	Zo	1	FI
Miconia corallina Spring *ex* Mart.	Ph	En	Zo	2	FI
Miconia pepericarpa Mart. *ex* DC.	Ph	En	Zo	1	FI
Miconia sellowiana Naudin	Ph	En	Zo	3	FI
Microlicia crenulata Mart.	Hm	En	Au	1	OA
Microlicia pseudoscoparia Cogn.	Hm	En	Au	1	OA
Tibouchina cordifolia Cogn.	Ph	En	Au	1	OA
Tibouchina multiflora (Gardn.) Cogn.	Hm	En	Au	4	OA
Trembleya parviflora (Don.) Cogn.	Ph	En	Au	2	OA
MELIACEAE					
Cabralea canjerana (Vell.) Mart.	Ph	En	Zo	2	FI
MORACEAE					
Dorstenia brasiliensis Lam.	Hm	En	Zo	1	OA
MYRSINACEAE					
Myrsine coriacea Sieber *ex* DC.	Ph	En	Zo	2	OA
Myrsine lancifolia Mart.	Ph	En	Zo	2	FI
Myrsine umbellata Mart.	Ph	En	Zo	2	FI
MYRTACEAE					
Blepharocalyx salicifolius (Kunth) O. Berg	Ph	En	Zo	1	FI
Calyptranthes cordata O. Berg	Ph	En	Zo	1	FI
Eugenia bella Phil.	Ph	En	Zo	1	FI
Eugenia bimarginata O. Berg	Ph	En	Zo	1	FI
Eugenia cavalcanteana Mattos	Ph	En	Zo	1	FI
Eugenia eurysepala Kiaersk.	Ph	En	Zo	2	FI
Eugenia punicifolia (Kunth) DC.	Ph	En	Zo	1	FI
Eugenia sonderiana O. Berg	Ph	En	Zo	4	FI
Gomidesia kunthiana O. Berg	Ph	En	Zo	1	FI
Myrceugenia alpigena (DC.) Landrum	Ph	En	Zo	2	OA
Myrcia breviramis (O.Berg) D.Legrand	Ph	En	Zo	1	FI

Continues

Appendix. Continuation

Species	LF	PS	DS	N	Phy
Myrcia crassifolia (Miq.) Kiaersk.	Ph	En	Zo	1	FI
Myrcia eriocalyx DC.	Ph	En	Zo	2	OA
Myrcia lasiantha DC.	Ph	En	Zo	1	FI
Myrcia mutabilis (O.Berg)N.J.E.Silveira	Ph	En	Zo	2	FI
Myrcia obovata Nied.	Ph	En	Zo	2	FI
Myrcia palustris DC.	Ph	En	Zo	1	FI
Myrcia splendens (Sw.) DC.	Ph	En	Zo	3	FI
Myrcia subcordata DC.	Ph	En	Zo	1	FI
Myrciaria glanduliflora (Kiaersk.) Mattos	Ph	En	Zo	2	FI
Siphoneugena densiflora O. Berg	Ph	En	Zo	3	FI
NYCTAGINACEAE					
Guapira obtusata (Jacq.) Little	Ph	En	Zo	1	FI
Guapira opposita (Vell.)Reitz	Ph	En	Zo	2	FI
OCHNACEAE					
Ouratea semiserrata (Mart. & Nees) Engl.	Ph	En	Zo	4	FI
OLACACEAE					
Ximenia americana L.	Ph	En	Zo	1	FI
ONAGRACEAE					
Fuchsia regia (Vell.) Munz	Li	Or	Zo	1	FI
ORCHIDACEAE					
Acianthera limae (Porto & Brade) Pridgeon & M.W. Chase	Ch	En	Ane	1	OA
Acianthera teres (Lindl.) Borba	Ch	En	Ane	4	OA
Bifrenaria tyrianthina (Loudon) Rchb. f.	Ch	En	Ane	1	OA
Epidendrum campestre Lindl.	Ch	En	Ane	1	OA
Epidendrum martianum Lindl.	Ch	En	Ane	2	OA
Epidendrum secundum Jacq.	Ch	En	Ane	3	OA
Galeandra montana Barb. Rodr.	Cr	En	Ane	1	OA
Maxillaria madida Lindl.	Ch	En	Ane	1	OA
Oncidium blanchetii Rchb.f.	Ch	En	Ane	2	OA
Oncidium gracile Lindl.	Ch	En	Ane	2	OA*
Oncidium pirarene Rchb. f.	Ch	En	Ane	1	OA
Oncidium warmingii Reichb. f.	Ch	En	Ane	2	OA
Pelexia aff. *bonariensis* (Lindl.) Schltr.	Ch	En	Ane	1	OA
Prescottia montana Rodrig.	Cr	En	Ane	1	OA
Prescottia oligantha Lindl.	Cr	En	Ane	1	FI
Prosthechea vespa (Vell.)W.E.Higgins	Ch	En	Ane	2	OA
Sacoila lanceolata (Aubl.) Garay	Cr	En	Ane	2	OA
Sarcoglottis schwackei Schltr.	Cr	En	Ane	1	OA
Sophronitis caulescens (Lindl.) C. Berg &. M.W. Chase	Ch	En	Ane	3	OA
Sophronitis crispata (Thunb.) C. Berg &. M.W. Chase	Ch	En	Ane	4	OA
Sophronitis liliputana (Pabst) C. Berg &. M.W. Chase	Ch	En	Ane	1	OA
Zygopetalum mackayi Hook.	Hm	En	Ane	1	FI
Zygopetalum maculatum (Humb., Bonpl. & Kunth) Garay	Hm	En	Ane	1	FI
OROBANCHACEAE					
Esterhazya splendida Mikan	Hm	Or	Au	1	OA

Continues

Appendix. Continuation

Species	LF	PS	DS	N	Phy
PASSIFLORACEAE					
Passiflora amethystina J. C. Mikan	Li	En	Zo	1	FI
Passiflora haematostigma Mart. *ex* Mast.	Li	En	Zo	1	FI
Passiflora speciosa Gardner	Li	En	Zo	1	FI
Passiflora villosa Vell.	Li	En	Zo	1	OA
PHYLLANTHACEAE					
Phyllanthus klotzschianus Muell. Arg.	Ph	En	Au	1	OA
Phyllanthus rosellus Müll. Arg.	Ch	En	Au	2	OA
Phyllanthus submarginatus Müll.Arg.	Ch	En	Au	1	OA
PHYTOLACACEAE					
Microtea paniculata Moq.	Te	En	Zo	2	OA
PIPERACEAE					
Peperomia decora Dahlst.	Ch	Am	Zo	2	OA
Peperomia galioides Kunth	Hm	Am	Zo	3	FI
POACEAE					
Andropogon bicornis L.	Hm	An	Ane	2	OA
Andropogon ingratus Hack.	Hm	An	Ane	3	OA
Andropogon leucostachyus Kunth	Hm	An	Ane	2	OA
Aristida gibbosa (Nees) Kunth	Hm	An	Ane	1	OA
Axonopus siccus Kuhlm.	Hm	An	Au	4	OA
Chusquea nutans L.G.Clark	Hm	An	Au	1	OA
Echinolaena inflexa (Poir.) Chase	Hm	An	Au	1	OA
Melinis minutiflora P. Beauv.	Hm	An	Au	2	OA
Melinis repens (Willd.) C. E. Hubb.	Te	An	Au	1	OA
Microchloa indica (L. f.) P. Beauv.	Te	An	Au	1	OA
Panicum cyanescens Nees	Hm	An	Au	2	OA
Panicum maximum Jacq.	Hm	An	Au	1	OA
Panicum polycomum Trin.	Hm	An	Au	1	OA
Panicum pseudisachne Mez	Hm	An	Au	1	OA
Panicum rude Nees	Hm	An	Au	1	OA
Panicum sellowii Nees	Hm	An	Au	3	OA
Paspalum erianthum Nees *ex* Trin.	Hm	An	Ane	1	OA
Paspalum minarum Hack.	Hm	An	Ane	1	OA
Paspalum polyphyllum Nees	Hm	An	Ane	2	OA
Paspalum scalare Trin.	Hm	An	Ane	3	OA
Schizachyrium tenerum Nees	Hm	An	Ane	1	OA
Setaria parviflora (Poir.) Kerguélen	Te	An	Au	1	OA
Sporobolus acuminatus Hack.	Hm	An	Au	1	OA
Sporobolus aeneus Kunth	Hm	An	Au	1	OA
Sporobolus metallicolus Longhi Wagner & Boechat	Hm	An	Au	2	OA
POLYGONACEAE					
Coccoloba acrostichoides Cham.	Ph	En	Zo	1	OA
Coccoloba scandens Casar.	Li	En	Zo	1	FI
PORTULACACEAE					
Portulaca hirsutissima Cambess.	Ch	En	Au	1	OA

Continues

Appendix. Continuation

Species	LF	PS	DS	N	Phy
ROSACEAE					
Prunus myrtifolia (L.) Urb.	Ph	En	Zo	1	FI
RUBIACEAE					
Borreria capitata (Ruiz & Pav.)DC.	Te	En	Au	3	OA
Coccocypselum aureum Cham. & Schltdl.	Hm	En	Zo	1	OA
Coccocypselum lanceolatum (Ruiz & Pav.)	Hm	En	Zo	3	FI
Cordiera concolor (Cham.) Kuntze	Ph	En	Zo	3	FI
Cordiera rigida (K.Schum.) Kuntze	Ph	En	Zo	1	FI
Declieuxia oenanthoides Mart. & Zucc.	Hm	En	Zo	1	OA
Faramea cyanea Müll. Arg.	Ph	En	Zo	1	FI
Galianthe cf. *angustifolia* (Cham. & Schltdl.)	Hm	En	Zo	1	OA
Posoqueria latifolia (Rudge) Roem. & Schult.	Ph	En	Zo	1	FI
Psychotria vellosiana Benth.	Ph	En	Zo	3	FI
Psyllocarpus laricoides Mart. & Zucc.	Ch	En	Au	1	OA
Remijia ferruginea (A. St.-Hil.) DC.	Ph	En	Zo	1	FI
SALICACEAE					
Casearia arborea (Rich.)Urb.	Ph	En	Zo	1	FI
Xylosma ciliatifolia (Clos) Eichler	Ph	En	Zo	1	FI
SANTALACEAE					
Phoradendron crassifolium (Pohl *ex* DC.)	Hp	En	Zo	1	FI
SAPINDACEAE					
Matayba marginata Radlk.	Ph	En	Zo	1	FI
Matayba mollis Radlk.	Ph	En	Zo	3	FI
Paullinia carpopoda Cambess.	Li	En	Zo	2	FI
Serjania acutidentata Radlk	Li	En	Ane	2	FI
Serjania gracilis Radlk.	Li	En	Ane	2	FI
SMILACACEAE					
Smilax ridida Russ. *ex* Steud.	Hm	An	Zo	1	OA
SOLANACEAE					
Athenaea micrantha Sendt.	Ph	En	Zo	1	FI
Aureliana fasciculata (Vell.) Sendtn.	Ph	En	Zo	1	FI
Aureliana velutina Sendt.	Ph	En	Zo	1	FI
Brunfelsia brasiliensis (Spreng.) L.B.Sm. & Downs	Ph	En	Zo	3	FI
Calibrachoa elegans (Miers) Stehman & Semir	Ch	En	Au	1	OA
Schwenkia americana L.	Hm	En	Ane	1	OA
Solanum americanum Mill.	Hm	En	Zo	1	OA
Solanum cladotrichum Dunal	Ph	En	Zo	3	FI
Solanum didymum Dunal	Ph	En	Zo	1	FI
Solanum granuloso leprosum Dunal	Ph	En	Zo	1	FI
Solanum isodynamum Sendtn.	Hm	En	Zo	1	OA
Solanum leptostachys Dun.	Ph	En	Zo	1	OA
Solanum lycocarpum A.St.-Hil.	Ph	En	Zo	1	OA
Solanum refractifolium Sendtn.	Hm	En	Zo	1	OA
Solanum stenandrum Dunal	Hm	En	Zo	3	OA
Solanum subumbellatum Vell.	Ph	En	Zo	1	FI

Continues

Appendix. Continuation

Species	LF	PS	DS	N	Phy
Solanum velleum Roem. & Schult.	Ph	En	Zo	1	FI
VELLOZIACEAE					
Barbacenia bicolor Mart.	Ch	Or	Au	1	OA
Barbacenia tricolor Mart.	Ch	Or	Au	1	OA
Vellozia albiflora Pohl	Ch	En	Au	1	OA
Vellozia caruncularis Mart. *ex* Seub.	Ch	Or	Au	2	OA
Vellozia compacta Mart. *ex* Schult. f.	Ph	Or	Au	4	OA
Vellozia crassicaulis Mart. *ex* Schult. f.	Ch	Or	Au	1	OA
Vellozia graminea Pohl	Ch	En	Au	3	OA
Vellozia tragacantha (Mart. *ex* Schult. f.) Mart. *ex* Seubert	Ch	En	Au	2	OA
VERBENACEAE					
Lantana camara L.	Ph	En	Zo	2	FI
Lantana fucata Lindl.	Ph	En	Zo	1	FI
Lippia elegans Cham.	Ph	En	Zo	1	OA
Lippia gracilis Schauer	Ph	En	Au	3	OA
Lippia hermannioides Cham.	Ph	En	Au	2	OA
Lippia sericea Cham.	Hm	En	Au	1	OA
Stachytarpheta confertifolia Moldenke	Hm	Or	Au	1	OA
Stachytarpheta glabra Cham.	Ph	Or	Au	2	OA
Stachytarpheta mexiae Moldenke	Ph	Or	Au	1	OA
VITACEAE					
Cissus albida Cambess.	Li	En	Zo	1	FI
Cissus subrhomboidea (Baker) Planch.	Li	En	Zo	1	FI
VOCHYSIACEAE					
Vochysia emarginata (Vahl) Poir.	Ph	En	Ane	1	FI