INTRODUCTION

The Atlantic forest is one of the main hotspots of biodiversity in the world with the highest conservation priorities (Morellato & Haddad, 2000; Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000). While the Atlantic forest was covering most of eastern Brazil prior to European colonization, it has now been reduced to only 7%–8% of its original area (Fundação SOS Mata Atlântica, INPE, 2011) and...
the regeneration of disturbed sites of the restingas. Scarano (2009) hypothesized that locally rare or subordinate species might become more abundant after disturbances in the peripheral systems of the Atlantic rain forest and increase in abundance after disturbances, such as fire (Cirne & Scarano, 2001), probably due to strong clonal growth.

Restingas are located outside the main core formation of the Atlantic rain forest, and despite high threats in these areas, they are often neglected in conservation policies (Scarano, 2009). Therefore, these ecosystems are understudied, and we know little about their capacity to regenerate after disturbances. Previous studies found no evidence of recovery to wood extraction in terms of tree species richness, even 10 years after the perturbation (Scarano, Rios, & Esteves, 1998). The removal of locally rare trees led to the death of bromeliads, which were germination sites for the trees themselves (Scarano, 2006). Such findings highlight the fragility and the low resilience of these peripheral ecosystems and call for better understanding of the mechanisms driving community assembly in order to provide efficient restoration and conservation strategies. Active restoration (e.g., native tree and shrub plantation) has been successful in the restingas, upon condition that exotic grass is removed (Zamith & Scarano, 2006), and in swamp forests despite high interspecific variation in the responses to plantation (Zamith & Scarano, 2010). Unfortunately, as mentioned above, restoration of restinga plant communities is not a priority and is also relatively expensive, especially in highly disturbed areas. The question remains of whether there is a role for passive restoration (e.g., natural regeneration, see Holl & Aide, 2011) in disturbed restingas of the Atlantic forest.

Vegetation surveys in naturally recovering areas are an important tool for identifying framework species, that is, native species that could be planted to accelerate natural regeneration and encourage biodiversity recovery on degraded sites (Blakesley et al., 2002; Dias et al., 2014; Elliott, 2003). In this regard, species richness represents the most frequent indicator in studies that measure restoration success (see Wortley, Hero, & Howes, 2013). In a recent global meta-analysis, species richness was considered as the main indicator to quantify how far restoration projects are from reference ecosystems (see Crouzeilles et al., 2016) and it is associated with ecosystem functioning (Aerts & Hoynay, 2011; Bu, Zang, & Ding, 2014; Liang et al., 2016).

In this study, we aimed at determining long-term vegetation recovery of a sand-mined site in restinga vegetation in Brazil, 16 years after the end of the disturbance. Here, we consider plant community composition and species diversity as two indicators of the recovery of ecosystem functions. We determined the recovery of plant community composition and species diversity using vegetation surveys carried out in undisturbed and sand-mined sites. Vegetation recovery is generally slow in tropical coastal plant communities, and we expected that the diversity and abundance values were still low in the mined site, even 16 years after the end of the perturbation. However, due to clonal regrowth and spatial proximity between the two sites, we expected similar floristic composition (in terms of species and life forms) in mined and undisturbed sites. Our goals were to
assess the success of passive restoration by identifying which species recolonize the sand-mined site and by estimating the degree of plant community recovery after disturbance. We also discuss the implications of our findings for restoration and conservation strategies in the peripheral ecosystems of the Atlantic forest.

2 | METHODS

2.1 | Study site and sampling

The study was conducted in the Paulo César Vinha State Park (1,574.85 ha), in the municipality of Guarapari (20°33′S and 40°26′W), located in a sandy coastal plain community in southeast Brazil. The park was created in 1990 under the designation of Setiba State Park, and it was renamed as Paulo César Vinha State Park in 1994 (http://www.meioambiente.es.gov.br/), in honor of the environmentalist Paulo César Vinha, killed for denouncing the sand-mining activities within the park. Sand removal (probably by backhoe) ended in 1994. A large sand-mined area covering about 1.2 ha (maximum 3.25 m depth) and with exposed clayish substrate from Tertiary sediments (Teixeira, Gillison, & Silva, 2014) was chosen as a representative site for the study.

We used vegetation data from Ferreira and Silva (2014). Briefly, sampling took place between April and July 2010. Thirty-eight 10 m × 10 m plots were inventoried: 20 within the sand-mined site and 18 in an adjacent undisturbed site, which was used as reference ecosystem (sensu White & Walker, 1997), totaling 2,000 m² and 1,800 m² of the sampled area for each site, respectively. Plots in the sand-mined site were distributed from the center of the mined area corresponding to more intense mining disturbance to the edges corresponding to lower mining disturbance. The minimum distance between the two sites was of 20 m. All plant species, regardless of the life form (trees, shrubs, and herbs), with a minimum of 1.5 cm of diameter at the soil level were sampled in each plot. We used three variables to describe each plot within the sand-mined site: the slope (inclination of the terrain, in degrees), distance from the plot to the center of the mined area (i.e., “distance”), and depth (the vertical distance between the ground level at the edge of the mined area and the plot).

2.2 | Data analysis

All analyses were carried out in the R environment (R Development Core Team, 2015) using the vegan package (Oksanen et al., 2015). We began our analytical procedures by running a multivariate sample sufficiency test (Anderson & Santana-Garcon, 2015) using the Bray–Curtis distance in log-transformed abundances for the two sets of plots (sand-mined and undisturbed). Then, we plotted rank-abundance curves (Magurran, 2004; Whittaker, 1965) for sand-mined and undisturbed sites. This procedure allowed us to identify graphically different components of species diversity. The length of the tail indicated the number of species, while equitability is checked by curve inclination; the more the curve is inclined, the lower is its equitability (Magurran, 2004; Melo, 2008). Further, Rényi diversity profiles (Anand & Orlóci, 1996; Rényi, 1961; Tóthmérész, 1995) were built for sand-mined and undisturbed sites. The most common diversity indices, such as Shannon and Simpson, are special cases of the Rényi generalized entropy:

\[ H_{\alpha} = \frac{1}{1-\alpha} \ln \sum_{i=1}^{S} p_i^\alpha \]

where \( H \) is the value of Rényi entropy for a given \( \alpha \) and \( p_i \) is the proportional representation of each component \( S \). Increasing values of \( \alpha \) will return different measures of diversity, each one giving more weight to the abundance of component species. When \( \alpha = 0 \), \( H \) corresponds to the logarithm of the richness. When \( \alpha \) gets closer to 1, \( H \) tends toward the Shannon diversity index, whereas when \( \alpha = 2 \), \( H \) corresponds to the inverse of the Simpson index (1/D). High-order entropy values are preferable because it is where \( H \) reaches stability (Anand & Orlóci, 1996; Duarte, Machado, Hartz, & Pillar, 2006). A community will be considered more diverse than another community when all its Rényi entropy values are higher than those of the other community (Tóthmérész, 1995). Rarefaction curves were used to test whether sites differ in species richness irrespective of differences in plant abundance (Gotelli & Colwell, 2001).

Moreover, species were ranked by their importance value index (IV, Brower, Zar, & von Ende, 1998; Dias, de Mattos, Vieira, Azeredo, & Scarano, 2006) for sand-mined and undisturbed sites in order to identify dominant, subordinate, and transient species in the sites (see Grime, 1998; Mariotte, 2014; Whittaker, 1965). This was made within each life form (trees/shrubs and herbs) and was based on the sum of three components: relative frequency, relative density, and relative abundance values of each species.

Principal component analysis (PCA) was used to identify the main trends in variation of species composition in both sites. Abundance data were Hellinger-transformed prior to ordination analysis (Legendre & Gallagher, 2001). We used a permutation multivariate ANOVA (PERMANOVA; Anderson, 2001) to test the differences in plant composition between undisturbed and sand-mined sites, coded as factors. This analysis was run on a Bray–Curtis distance of a log₂-transformed abundance matrix. Between-site differences may be due to differences in location of the factors in the multivariate space of ordination (i.e., suggesting a local effect), or to the dispersion of the values in relation to the centroid within each factor (i.e., suggesting a high beta diversity within sites), or both (Anderson, Ellingsen, & McArdle, 2006; Warton, Wright, & Wang, 2012). To check this, we ran a permutation analysis of multivariate dispersion (PERMDISP; Anderson et al., 2006) on the same log₂-transformed abundance matrix using Bray–Curtis distance. Finally, a redundancy analysis (RDA; Legendre & Legendre, 2012) was run between species abundances × plot matrix (using only the 20 plots within the sand-mined area) constrained by three variables describing terrain features of the sand-mined area: slope (in degrees), depth (in meters), and distance from the center of the mined area (in meters). These field features were standardized (scaled to zero mean and unit
variance) prior to analysis (McGarigal, Cushman, & Stafford, 2000), and absolute abundances of species data were log-transformed prior to analysis (Legendre & Legendre, 2012). We used the vegan’s ordistep function (Borcard, Gillet, & Legendre, 2011) to select the most related field features to the variation in the community matrix. Given the fact that there is only one site in each disturbance level, a case of pseudoreplication (Hurlbert, 1984), the scope of our comparisons is limited to the local conditions tested. Thus, we use general knowledge to discuss our findings in comparison with other locations where the conditions are typical (see Webster, 2007), and we emphasize the importance to use our main conclusions as new hypotheses to be tested (see Davies & Gray, 2015) in other tropical coastal vegetations.

3 | RESULTS

The multivariate sample sufficiency test showed that the number of plots in each site was sufficient to compare both sites, given the stability of the curve and the reduction in the envelope size (Figure 1). Sand-mined and undisturbed sites differed in the shape of their rank–abundance curves (Figure 2a). The curve of sand-mined site was less inclined than that of the undisturbed site, thus reflecting a higher evenness. The total number of species was higher in the undisturbed site (41 species) by comparison with the sand-mined site (27 species). However, diversity was higher in the sand-mined site due to the lower equitability of the undisturbed site (Figure 2b). Nonetheless, the rarefaction curves showed that there was no difference in species richness between the sites when controlling for density effects (Figure 3a), despite higher shrub species richness in the undisturbed site (Figure 3b).

Sand-mined and undisturbed sites differed in the shape of their rank IVI curves and in the identity of dominant and subordinate species for both herb (Figure 4a) and tree/shrub species (Figure 4b). In the undisturbed site, herbaceous dominant species (n = 2) were the bromeliads, Aechmea lingulata and Vriesea neoglutinosa, and herbaceous subordinate species (n = 3) were Vriesea procera (bromeliad), Allagoptera arenaria (geophyte palm), and Pilosocereus arrabidae (cactus). In the sand-mined site, herbaceous dominants (n = 4) were the climbing plant Paullinia weinmannifolia (scandent vine), the cactus Cereus fernambucensis, the spurge Microstachys corniculata, and the pipewort Comanthera imbricata (Figure 4a). In the undisturbed

FIGURE 1  Result of the multivariate sample sufficiency procedure based on Bray–Curtis distance. Sample size sufficiency is given by both the stability in the curve (mean multivariate pseudo standard error) and reduction in the envelope sizes (percentiles, 2.5 and 97.5, after bootstrapping)

FIGURE 2  Abundance and diversity patterns of the undisturbed and sand-mined sites in the coastal sandy plant community. (a) Changes in relative plant abundance in the undisturbed and sand-mined sites. The y-axis shows the cumulative relative abundance (species ranked by relative cover in the ascending order and cumulated). The x-axis shows the species rank in the descending order, from the most to the less abundant plant species. The steepest slope of the undisturbed site dominance profile highlights higher plant dominance and thus lower diversity than the sand-mined site. Calculations are independent for each site. (b) Diversity profile using the Rényi series. Dashed gray line indicates α = 1, which corresponds to the Shannon’s diversity (H’). The undisturbed site was species rich, but its lower equitability (J) lowered the diversity outputs for α-values higher than 0.5

FIGURE 3a  Result of the multivariate sample sufficiency procedure based on Bray–Curtis distance. Sample size sufficiency is given by both the stability in the curve (mean multivariate pseudo standard error) and reduction in the envelope sizes (percentiles, 2.5 and 97.5, after bootstrapping)
and the subordinate tree/shrub species (n, Guapira pernambucensis) site, the dominant shrub species (n, Baccharis reticularia) site, Protium icicariba, while the subordinates (n = 6) were the tree species Clusia hilariana, Neomitranthes obtusa, and Ouratea cuspidata and the shrubs Baccharis reticularia, Guapira pernambucensis, and Guapira opposita. In the sand-mined site, the dominant shrub species (n = 1) was Chamaecrista ramosa and the subordinate tree/shrub species (n = 6) were Ocotea notata, Guapira pernambucensis, Baccharis reticularia, Lepidaploa rufogrisea, Schinus terebinthifolius, and Garcinia brasiliensis. See Appendix for the list of species, abundances, frequencies, and IVI values in both sites.

The differences in composition and abundance between the two sites were significant (PERMANOVA, p < .001) and are shown in the first two axes (39%) of the ordination graph (Figure 5). Moreover, composition differences between the sites can also be attributed to the within-site dispersion in beta diversity (PERMDISP, p < .001). PCA axis 1 showed that different species dominated the sand-mined and the undisturbed sites. However, PCA axis 2 showed that sand removal did not produce the same effects on all plots within the sand-mined site with plots dominated by M. corniculata and other by C. imbricata, although both species were initially rare or subordinate species according to the reference site data. Field attributes ("depth" and "distance") were significantly associated with the compositional patterns within the sand-mined site, as shown by the RDA (p = .001; Figure 6), and show that the abundance of M. corniculata was higher in the deeper portions of the mined area (i.e., where sand has been more deeply mined). Conversely, C. imbricata was more abundant with increasing distance from the center of the sand-mined area where mining disturbance was less important.

FIGURE 3 Rarefaction curves and species richness of the life forms in undisturbed and sand-mined sites in the coastal sandy plant community. (a) Vertical line shows confidence interval (±2 SE) for the number of individuals in a sample of the undisturbed site. The species richness did not differ between undisturbed and sand-mined sites when the number of individuals sampled in these sites is taken into account. (b) Differences in species richness relative to plant life forms. The richness of shrub species is higher in the undisturbed area than in the sand-mined area.

4 | DISCUSSION

Previously exploited sand-mined areas differed from undisturbed site in terms of plant species composition patterns, even 16 years after the end of the disturbance. This confirms previous findings highlighting the slow vegetation recovery following sand mining (Partridge, 1992). While species richness recovered, dominance was higher in the sand-mined site and the identity of dominant and subordinate species greatly differed from the reference site. The regeneration of the sand-mined site was principally driven by the increased abundance of the original subordinate or transient species (i.e., those of the preserved site), while well-known nurse plants were absent or present in very low abundances. Such findings point to the importance of taking plant community floristic composition into account, indicating that passive restoration alone may not suffice and that human intervention may become necessary.

Resprouting often drives plant community composition after disturbances (Cirne & Scarano, 2001; Simões & Marques, 2007). Sand removal may have affected the potential for natural regeneration through resprouting. Moreover, local conditions such as depth (a proxy for bottom watering conditions; the deeper is the mining, the less well drained is the soil) and distance to the center of the mined area explained the differences in plant community composition, within the recovering sand-mined site. Only the initially subordinate or rare species were able to colonize the center of the mined area with exposed Tertiary sediments. These findings suggest that differences in soil conditions between Quaternary (i.e., undisturbed site) and Tertiary sediments (i.e., sand-mined site), and water availability are crucial for effective plant colonization of mined areas. Future studies should therefore determine the performance of the dominant and subordinate species in different types of soil (Tertiary vs. Quaternary) and moisture status (drained vs. water accumulation). This could help understand why dominant species of the undisturbed site did not successfully establish in the mined area and to identify framework species, which can accelerate plant recolonization of the mined site, especially in the slopes of the mined area.

Interestingly, the species that are becoming dominants in the sand-mined site are not those for what we have knowledge
Our results indicate that the dominance of herbaceous and shrub species in disturbed restingas can significantly impact community structure. Specifically, the presence of certain species, such as *Aechmea lingulata*, *Aechmea nudicaulis*, and *Clusia hilariana*, can have a positive effect on the overall community by providing facilitative benefits to other species. These facilitative species, which are typically nurse plants, are crucial in accelerating the successional process in disturbed ecosystems.

Community-level patterns and processes are crucial to understand and manage natural systems (Simberloff, 2004). This is because management is, basically, a local activity. Restoration of the highly impacted coastal plant communities is an urgent demand in many parts of the world, and positive interactions can help to achieve this target (Lithgow et al., 2013). We show that the colonization of the disturbed site by well-known nurse plants was not achieved after 16 years of disturbance, thus emphasizing the need for active restoration. The proper selection of framework species will be crucial in this regard (see Dias et al., 2014), and the role of facilitative species is a key consideration in the success of active restoration efforts.
these naturally recovering species and well-known nurse plants as framework species will need to be tested along with the management of critical abiotic factors.

Our results raise the hypothesis that passive restoration of sandy coastal plains degraded by sand mining may not rely on the positive effects of typical nurse plants due to their absence or very low abundances in mined areas, even 16 years after disturbance. The long-term results found here point to the need to test these findings across a larger range of sand-mined sites. Rare or subordinate species in the undisturbed site became abundant in the mined area, and we suggest that these species should be screened in the future for their potential role as nurse plants. Moreover, diversity and richness alone were not good indicators of success because composition was quite different between regenerating and reference sites and well-known nurse plants were absent from the regenerating site. Lastly, active restoration should be tested in sand-mined sites by planting the nurse tree *Clusia hilariana* and/or by managing critical abiotic factors.

**FIGURE 5** Principal component analysis of plots in sand-mined (gray circles) and undisturbed (black triangles) described by the abundances of 45 herbaceous, shrub, tree and climber species. Axis 1 shows strong discrimination between undisturbed and sand-mined sites, while axis 2 shows differences within the sand-mined site with a contrast between plots dominated by *C. imbricata* and plots dominated by *M. corniculata*. *C. ramosa* dominated a single plot within the undisturbed site. Codes for species are the same as in Figure 4.

**FIGURE 6** Redundancy analysis of the sand-mined plots described by the species composition matrix in relation to selected field characteristics (depth and distance to the center of the mined area). Sand removal in some plots created deeper holes and exposed the sediments from the Tertiary layer, which both favored water accumulation and increased the abundance of *M. corniculata*. At the opposite, *C. imbricata* dominated the slopes within the sand-mined site and was more abundant in plots with long distance between the edges and the center of the mined area. Codes for species are the same as in Figure 4, except for the following: msu, *Manilkara subsericea* (Mart.) Dubard; lca, *Lantana camara* L.; gbr, *Garcinia brasiliensis* Mart.; pkl, *Phyllanthus klotzschianus* Müll.Arg.; ssa, *Serjania salzmanniana* Schltdl.; mni, *Melanopsis nigrum* Colla; ege, *Evolvulus genistoides* Ooststr.; tbu, *Tocoyena bullata* (Vell.) Mart.
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CONFLICT OF INTEREST

None declared.

AUTHOR CONTRIBUTIONS

MG and AS conceived and designed the research; PF, RB, PR, and AS performed the field survey and species’ identifications; MG, KM, and FM analyzed the data; MG, FM, KG-M, JS, and PM wrote and edited the manuscript.

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APPENDIX
Phytosociological table for herbaceous/climber and tree/shrub species in the undisturbed and sand-mined sites. IVI, importance value index

| Site condition | Life form | Species                  | Absolute density | Relative density | Absolute frequency | Relative frequency | Absolute dominance | Relative dominance | IVI  |
|----------------|-----------|--------------------------|------------------|------------------|--------------------|--------------------|--------------------|--------------------|------|
| Sand-mined     | Herbs     | *Paullinia weinmanniiifolia* | 2                | 1.39             | 10.00              | 3.85               | 0.16               | 57.16              | 62.40 |
|                |           | *Cereus fernambucensis*   | 23               | 15.97            | 40.00              | 15.38              | 0.04               | 15.65              | 47.01 |
|                |           | *Microstachys corniculata*| 34               | 23.61            | 45.00              | 17.31              | 0.01               | 4.59               | 45.51 |
|                |           | *Comanthera imbricata*    | 37               | 25.69            | 30.00              | 11.54              | 0.02               | 6.07               | 43.31 |
|                |           | *Evolvulus maximiliani*   | 13               | 9.03             | 30.00              | 11.54              | 0.00               | 0.98               | 21.55 |
|                |           | *Allagoptera arenaria*    | 7                | 4.86             | 25.00              | 9.62               | 0.01               | 4.72               | 19.19 |
|                |           | *Pilosocereus arrabidae*  | 9                | 6.25             | 20.00              | 7.69               | 0.01               | 4.14               | 18.08 |
|                |           | *Vriesea neoglutinosa*    | 6                | 4.17             | 20.00              | 7.69               | 0.00               | 1.42               | 13.27 |
|                |           | *Melocactus violaceus*    | 4                | 2.78             | 15.00              | 5.77               | 0.01               | 3.41               | 11.95 |
|                |           | *Serjania saltmanniana*   | 4                | 2.78             | 15.00              | 5.77               | 0.00               | 0.41               | 8.95  |
|                |           | *Vriesea procera*         | 4                | 2.78             | 5.00               | 1.92               | 0.00               | 1.38               | 6.09  |
|                |           | *Evolvulus genistoides*   | 1                | 0.69             | 5.00               | 1.92               | 0.00               | 0.07               | 2.69  |
|                |           | *Chamaecrista ramosa*     | 24               | 29.63            | 68.75              | 24.44              | 0.01               | 11.80              | 65.87 |
|                |           | *Ocotea notata*           | 8                | 9.88             | 31.25              | 11.11              | 0.01               | 18.69              | 39.67 |
|                |           | *Guapira pernambucensis*  | 10               | 12.35            | 31.25              | 11.11              | 0.01               | 14.69              | 38.15 |
|                | Trees/    | *Baccharis reticularia*   | 10               | 12.35            | 25.00              | 8.89               | 0.01               | 16.03              | 37.26 |
| shrubs         |           | *Lepidaploa rufogrisea*   | 10               | 12.35            | 31.25              | 11.11              | 0.00               | 4.67               | 28.13 |
|                |           | *Schinus terebinthifolius*| 1                | 1.23             | 6.25               | 2.22               | 0.01               | 20.95              | 24.41 |
|                |           | *Garcinia brasiliensis*   | 5                | 6.17             | 18.75              | 6.67               | 0.00               | 7.12               | 19.96 |
|                |           | *Protium icicariba*       | 2                | 2.47             | 12.50              | 4.44               | 0.00               | 1.47               | 8.39  |
|                |           | *Neomitranthes obtusa*    | 2                | 2.47             | 12.50              | 4.44               | 0.00               | 0.83               | 7.74  |
|                |           | *Tocoyena bullata*        | 2                | 2.47             | 12.50              | 4.44               | 0.00               | 0.68               | 7.59  |
|                |           | *Manilkara subsericea*    | 2                | 2.47             | 6.25               | 2.22               | 0.00               | 0.99               | 5.68  |
|                |           | *Phyllanthus klotzschianus*| 2              | 2.47             | 6.25               | 2.22               | 0.00               | 0.77               | 5.47  |
|                |           | *Kielsmeyera albopunctata*| 1                | 1.23             | 6.25               | 2.22               | 0.00               | 0.50               | 3.95  |
|                |           | *Melanopsidium nigrum*    | 1                | 1.23             | 6.25               | 2.22               | 0.00               | 0.50               | 3.95  |
|                |           | *Lantana camara*          | 1                | 1.23             | 6.25               | 2.22               | 0.00               | 0.32               | 3.77  |

(Continues)
| Site condition | Life form | Species                  | Absolute density | Relative density | Absolute frequency | Relative frequency | Absolute dominance | Relative dominance | IVI   |
|----------------|-----------|--------------------------|------------------|------------------|--------------------|--------------------|--------------------|--------------------|-------|
| Undisturbed    | Herbs     | *Aechmea lingulata*      | 417              | 52.32            | 70.59              | 17.14              | 0.80               | 51.90              | 121.37|
|                |           | *Vriesea neoglucinosa*   | 177              | 22.21            | 70.59              | 17.14              | 0.29               | 18.72              | 58.08|
|                |           | *Vriesea procer*         | 88               | 11.04            | 41.18              | 10.00              | 0.18               | 11.58              | 32.62|
|                |           | *Allagoptera arenaria*   | 46               | 5.77             | 88.24              | 21.43              | 0.08               | 4.94               | 32.14|
|                |           | *Pilosocereus arrabidae* | 19               | 2.38             | 35.29              | 8.57               | 0.13               | 8.09               | 19.04|
|                |           | *Cereus fernambucensis*  | 10               | 1.25             | 23.53              | 5.71               | 0.02               | 1.22               | 8.19  |
|                |           | *Comanthera imbricata*   | 18               | 2.26             | 11.76              | 2.86               | 0.02               | 1.20               | 6.32  |
|                |           | *Evolvulus maximiliani*  | 4                | 0.50             | 17.65              | 4.29               | 0.00               | 0.14               | 4.92  |
|                |           | *Anthurium intermedium*  | 7                | 0.88             | 11.76              | 2.86               | 0.00               | 0.10               | 3.84  |
|                |           | *Melocactus violaceus*   | 3                | 0.38             | 5.88               | 1.43               | 0.03               | 1.84               | 3.64  |
|                |           | *Evolvulus genistoides*  | 4                | 0.25             | 11.76              | 2.86               | 0.00               | 0.04               | 3.15  |
|                |           | *Stachytarpheta cayennensis* | 2        | 0.25             | 11.76              | 2.86               | 0.00               | 0.04               | 3.15  |
| Trees/shrubs  |           | *Hylocereus setaceus*    | 1                | 0.13             | 5.88               | 1.43               | 0.00               | 0.10               | 1.65  |
|                |           | *Serjania salzmanniana*  | 1                | 0.13             | 5.88               | 1.43               | 0.00               | 0.06               | 1.61  |
|                |           | *Kielmeyera albopunctata*| 88               | 23.85            | 88.89              | 11.43              | 0.78               | 63.76              | 99.04 |
|                |           | *Protium icicariba*      | 73               | 19.78            | 88.89              | 11.43              | 0.11               | 9.01               | 40.22 |
|                |           | *Clusia hilariana*       | 19               | 5.15             | 50.00              | 6.43               | 0.14               | 11.64              | 23.22 |
|                |           | *Neomitrantes obtusa*    | 28               | 7.59             | 50.00              | 6.43               | 0.03               | 2.72               | 16.74 |
|                |           | *Ouratea cuspidata*      | 23               | 6.23             | 33.33              | 4.29               | 0.03               | 2.65               | 13.17 |
|                |           | *Baccharis reticularia*  | 17               | 4.61             | 50.00              | 6.43               | 0.02               | 1.89               | 12.93 |
|                |           | *Guapira pernambucensis* | 17               | 4.61             | 55.56              | 7.14               | 0.01               | 1.05               | 12.80 |
|                |           | *Guapira opposita*       | 17               | 4.61             | 50.00              | 6.43               | 0.01               | 1.07               | 12.11 |
|                |           | *Myrciaria floribunda*   | 13               | 3.52             | 38.89              | 5.00               | 0.01               | 1.04               | 9.56  |
|                |           | *Tocoyena bullata*       | 10               | 2.71             | 38.89              | 5.00               | 0.00               | 0.38               | 8.09  |
|                |           | *Coccoloba floribunda*   | 10               | 2.71             | 33.33              | 4.29               | 0.01               | 0.84               | 7.84  |
|                |           | *Octeae notata*          | 9                | 2.44             | 27.78              | 3.57               | 0.01               | 0.64               | 6.65  |
|                |           | *Melanopsisidium nigrum* | 8                | 2.17             | 22.22              | 2.86               | 0.00               | 0.22               | 5.25  |
|                |           | *Erythroxylum subsessile*| 5                | 1.36             | 22.22              | 2.86               | 0.00               | 0.41               | 4.62  |
|                |           | *Manilkara subsericea*   | 4                | 1.08             | 22.22              | 2.86               | 0.00               | 0.18               | 4.13  |
|                |           | *Stigmaphyllon paralias* | 4                | 1.08             | 22.22              | 2.86               | 0.00               | 0.14               | 4.08  |
|                |           | *Chamaecrista ramosa*    | 4                | 1.08             | 16.67              | 2.14               | 0.00               | 0.27               | 3.50  |
|                |           | *Andira nitida*          | 4                | 1.08             | 11.11              | 1.43               | 0.00               | 0.40               | 2.91  |
|                |           | *Garcinia brasiliensis*  | 4                | 1.08             | 11.11              | 1.43               | 0.00               | 0.20               | 2.72  |
|                |           | *Agarista revoluta*      | 3                | 0.81             | 5.56               | 0.71               | 0.01               | 0.89               | 2.41  |
|                |           | *Lepidaploa rufogrisea*  | 2                | 0.54             | 11.11              | 1.43               | 0.00               | 0.06               | 2.03  |
|                |           | *Anacardium occidentale* | 2                | 0.54             | 5.56               | 0.71               | 0.00               | 0.15               | 1.40  |
|                |           | *Couepia ovalifolia*      | 2                | 0.54             | 5.56               | 0.71               | 0.00               | 0.13               | 1.38  |
|                |           | *Ternstroemia brasiliensis* | 1        | 0.27             | 5.56               | 0.71               | 0.00               | 0.19               | 1.17  |
|                |           | *Phyllanthus klotzschianus* | 1        | 0.27             | 5.56               | 0.71               | 0.00               | 0.03               | 1.02  |
|                |           | *Myrsine umbellata*      | 1                | 0.27             | 5.56               | 0.71               | 0.00               | 0.03               | 1.02  |