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STRUCTURAL AND ENVIRONMENTAL VARIABILITY FROM THE EDGE TO THE INTERIOR OF AN ATLANTIC FOREST REMNANT IN BRAZIL

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This study described the floristic-structural variations between edges consisting of one bordering the road and the other by the forest stands with the interior of the forest. The effects of the relationships between environmental aspects in the Atlantic Forest remnant in Brazil was also studied. The structure of the vegetation stratum differed between the edges with the interior and the relationship between the distribution of species with the environmental variables reflected the changes which occurred in the edges towards the interior. For vegetation sampling, 36 plots were established over an area of 0.9 ha and were distributed on both edges and inside the remnant. All individuals with diameter at breast height of ≥ 2.5 cm were measured and identified. The results revealed the differences in the structure and composition of species distribution pattern in the remnant were influenced by environmental variables such as humidity, resistance to penetration, cation exchange capacity and sodium and potassium contents. These results reinforced the need to create conservation strategies to minimise forest degradation and loss of biodiversity in these forest ecosystems.

Keywords: Edge effect, core area, matrix influence, fragment size, protected area

INTRODUCTION

The Atlantic Forest is one of the most biodiverse environments on the planet and listed as a priority biome in the Brazilian conservation policies (Rezende et al. 2018). The area not only has high species richness, high local and regional levels of endemism but also high susceptibility to degradation (Mittermeier et al. 2004). Based on the current situation of this biome, Laurance (2008) stated that few fragmented hotspots were vulnerable and may cause reduction of the Brazilian Atlantic Forest.

The fragmentation of ecosystems is the main factor for area and species loss (Magnago et al. 2014). Fragmentation is directly related to the changes in forest environment due to the influences of surrounding anthropised habitats and is known as edge effect (Murcia 1995, Meeussen et al. 2020). Changes in the microclimate of the fragment edge such as wind intensity, light levels, temperature and humidity (Harper et al. 2005) can influence the composition of tree species, vegetation structure, carbon stock, migration of animals and invasion of exotic species. Due to the anthropised external environment, the loss of genetic variability in native species is rampant (Zhang & Zang 2011, Wekesa et al. 2019).

Therefore, studies on vegetation and its relationship with environmental variables are of paramount importance, as they provide supports in the conservation and management of forest remnants (Souza et al. 2017) especially for the protected areas of the original Atlantic Forest, which consisted of only 1% of the total area (Ribeiro et al. 2009).

The study aimed to analyse the floristic-structural variations between the edges with the interior of the forest and the implications of the relationships between environmental aspects with the plant community. The two main objectives of this work were to determine the structure of the vegetation layer differences between the edges and the interior of the forest remnant and to study the relationship between the distribution of the plant species and the changes of environmental variables from the edges to the interior of the forest remnant.

MATERIALS AND METHODS

Study area

The study was conducted in a remnant of tropical dense ombrophilous lowland forest in the Córrego Grande Biological Reserve which is located in the municipality of Conceição da Barra (18°12′ S and 39° 45′ W) in the extreme north in the state of Espírito Santo in Brazil. Córrego Grande Biological Reserve has a triangular physiognomic shape of approximately 1504 ha (Figure 1), containing stands of *Eucalyptus* spp., pastures of private properties and an 8-km contiguous ground road named Picadão da Bahia, which constitutes the border between the states of Espírito Santo and Bahia (Rezende 2012). In the study, the following treatments areas were established; the road and the forest edges, mostly *Eucalyptus* stands and the interior of the remainder as control.

Before its conversion to a biological reserve (Brasil 1989), the area was a legal private property reserve (Rezende 2012). The reserve suffered a fire outbreak in 1987 which reached one third of its original vegetation cover and possibly in the areas of the sampling units, based on the description of former employees of the Conservation Unit (Rezende 2012). Despite the incident, after the result of 30 years of preservation it is considered a moderately disturbed area composed of an important forest remnant (Chiarello 2000) with an area of about 445 ha^2 (Costa et al. 2017).

The dense ombrophilous lowland forest is characterized by high temperatures and high well-distributed precipitation throughout the year (Garbin et al. 2017). The forest type is found in areas ranging from plains close to the coast to elevations between 20 to 200 m above sea level from Pernambuco to Rio de Janeiro (Rizzini 1997). Córrego Grande Biological Reserve is located at an elevation of 55 m (Costa et al. 2017). The climate of the region is humid tropical (Alvares 2013) with an average annual temperature of 23.9 °C and an average total precipitation of 1350 mm per year. The topography is mainly characterised by coastal tablelands with nutrient-poor soil (Peixoto et al. 2008).

Data sampling

Vegetation structure

Data collection was carried out from August 2017 to September 2018. For the sampling of vegetation, sampling plots in a fixed area were established (Mueller-Dombois & Ellenberg 1974). The sampling units were limited to ground road and forest stands and distributed in the interior of the forest and at two different edges. Three points were randomly determined with a minimum distance of 100 m between points in each sampling unit. At each point, four sample units with dimensions of 10 m × 25 m (250 m^2) were distributed, equidistant at 10 m and systematically allocated in the direction from the edge to the interior of the remnant forest. The total area sampled corresponded to 0.9 ha^2.

All tree and shrub individuals or woody stratum with diameter at breast height (DBH) ≥ 2.5 cm were measured. The individuals measured also included dead standings and were labelled with numbered aluminium plates.

Botanical specimens were collected and identified using reputable literature, dendrological keys and comparison with reference collections of herbariums in the region such as the Herbário Capixaba (CAP), Herbário Universidade Federal do Espírito Santo (VIES) and Herbário Reserva Natural Vale (CVRD).

The Angiosperm Phylogeny Group (APG IV 2016) was used for taxon classification. The species nomenclature and the abbreviations of the respective authors were checked according to the information available on the Missouri Botanical Garden website (www.tropicos.org) and on the lists in Flora do Brasil 2020 (www.reflora.jbrj.gov.br).

Supplementary materials

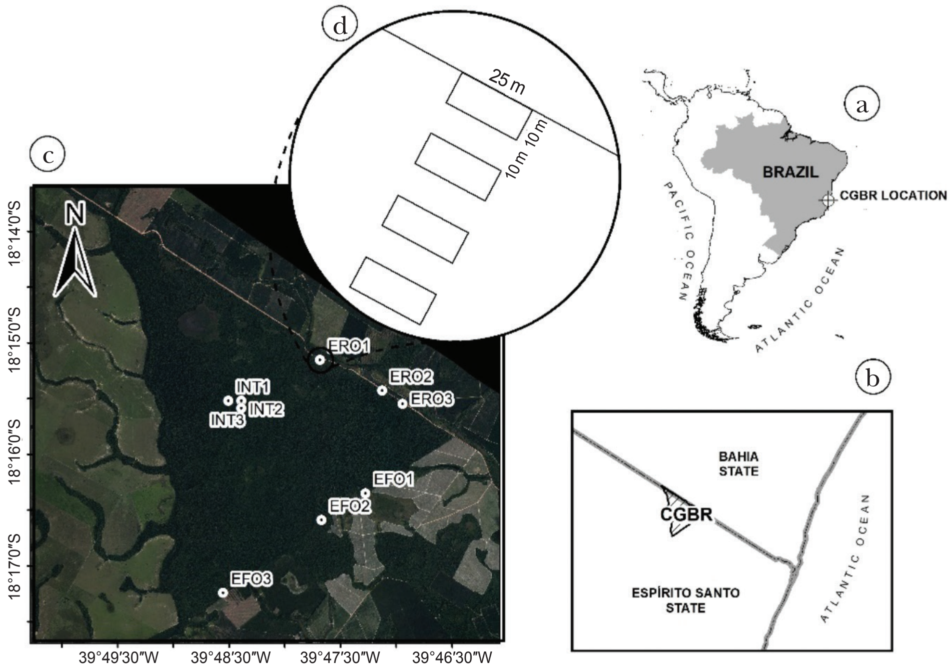

Figure 1 Location of the Córrego Grande Biological Reserve (CGBR) (a) and (b) with the allocation of sample units in the study area (c) and details of their distribution (d)
ERO = points that border the ground road, EFO = points that border the forest edge and INT = points within the forest

Environmental variables

In order to measure and capture incident light in the canopy, the method adopted from the work of Tichý (2016) by using a smartphone with an attached hemispheric lens was used to obtain hemispheric digital photographs. The photographs were recorded in the months of April during end of the period of greatest precipitation and in September during the end of the period of least precipitation of 2018. The photographs were captured at times of the day without the direct incidence of sunlight under the canopy and suitable atmospheric conditions to achieve greater uniformity of lighting. In each sampling unit, two photographs were obtained at two points, 5 m away from the plot boundaries to obtain an average distance per sampling unit. The images were processed using the Gap Light Analyzer Mobile software.

For soil characterisation study, soil samples were collected at five points consisting of four points at each vertex and one point at the centre of the sampling unit. In addition, three undisturbed soil samples were collected at a depth of 0–20 cm per plot in open trenches for soil density and moisture test. Subsequently, the collections were homogenised into composite. The composite was analysed for soil chemical and physical properties based the methodology proposed by EMBRAPA (2011). The physical-chemical attributes analyzed were as follows; pH, carbon, calcium, magnesium, potassium, sodium, phosphorus, nitrogen, potential acidity, organic matter, sum of bases, cation exchange capacity, sand content, clay content, silt content, moisture and soil density.

In order to determine the penetration resistance, an impact penetrometer was used and the number of strokes reaching a soil depth of 20 cm was recorded. The procedure was performed at five points in each plot, one near each vertex and the other in the centre of the sample unit. The resistance to soil penetration was calculated using the equation developed by Stolf et al. (2005).

Data analysis

The phytosociological parameters used for structural description of the community were calculated as suggested by MuellerDombois and Ellenberg (1974) for the three studied environments on road, forest edge and interior using the R.3.2.2 software (R-Core-Team 2017). The community individuals were divided into the three different environments and distributed in diametric and hypsometric classes according to the formula proposed by Spiegel et al. (2013).

In order to estimate the diversity and equability of species in the studied forest remnant, Shannon's diversity indices and Pielou's equitability indices (Magurran 2013) were calculated using the vegan package (Oksanen et al., 2018) of the R.3.2.2 software (R-Core-Team 2017). As the absolute density data of the study did not fulfil the assumptions of normality of residues in Shapiro-Wilk test and homogeneity of variances in Levene's homoscedasticity test, the variable was subjected to the non-parametric test of multiple comparisons in Kruskal-Wallis test to detect significant differences between the edges of the road, forest edge and the interior.

Species richness and diversities of the three sampled environments were evaluated in relation to the number of individuals and sample units, using the rarefaction and individual extrapolation curves. Species richness was built using the first Hill numbers (species richness, $q = 0$) and diversities using Shannon's exponential indices (species diversity, $q = 1$) (Chao et al. 2014). Extrapolations were made based on the abundance data, considering between two and three times the total sample size by types of environment (Colwell et al. 2012). Rarefaction or extrapolation curves based on individuals and sample units were calculated using the iNEXT package (Hsieh et al. 2016). Rarefaction curve was estimated as the average of 100 bootstrapping runs replicated to estimate 95% confidence intervals. Whenever the 95% confidence intervals did not overlap, the number of species differed significantly by $p < 0.05$ (Colwell et al. 2012). This analysis, as well as the preliminary tests of normality and homoscedasticity were carried out with the aid of the R.3.2.2 program (R-Core-Team 2017).

The species which characterized the floristic groupings for road, forest and inland edge study area were formed by the unweighted pair-group method with arithmetic mean method. Furthermore, the indicator species analysis was performed using the combination of relative abundance values and relative frequency of species (Dufrêne & Legendre 1997). The significance of the results obtained was verified by the Monte Carlo test, using the PC-ORD 6.08 program (McCune & Mefford 2011).

Analysis of a non-metric multidimensional scale was performed to verify possible differences in species similarity between the plots of the three environments. Ordination was performed using the Jaccard coefficient indices taking into account qualitative and presence-absence of species and by using Bray-Curtis analysis to access the quantitative and abundance-density of individuals of the species. Multivariate similarity analysis (one-way ANOSIM) was used to ascertain differences in the composition between areas and performed using Jaccard and Bray-Curtis dissimilarity indices with distances of 9999 permutations and a significance level of 0.01 (Clarke 1993). The analysis was performed using the PAST 3.13 program (Hammer et al. 2001).

Canonical correspondence analysis was performed to investigate the relationship between abiotic variables such as canopy opening, chemical, physical and resistance to soil penetration and biotic variables such as species. The ordistep function of the vegan package was used to select the variables that best explain the species distribution (Oksanen et al. 2018) and only variables with a variance inflation factor value < 2 were used. The significance of each abiotic variable was verified using Monte Carlo randomisations method and only species with > 10 individuals were used. Canonical Correspondence Analysis was later performed using the autoplot function of the ggplot2 package (Hadley 2015).

RESULTS

Vegetation structure

A total of 2426 individuals were sampled where 2268 (93.49%) were living sample and 158 (6.51%). All individuals were divided into road, forest edge and interior categories (Table 1), which allowed the estimation of density at 2696 individuals ha^{-1} and a basal area of 29.67 $m^2 ha^{-1}$. All living individuals were distributed in 69 botanical families and 147 genera (Appendix). A total of 335 species were recorded at the taxonomic levels where 89 morphotypes identified at the genus level, 38 morphotypes at the family level and 10 indeterminate morphotypes. The areas shared a total of 77 sampled species (Figure 2).

Table 1 Vegetation structure of individuals collected from the road edge, forest edge and inside forest remnant at Córrego Grande Biological Reserve, Brazil

	Road	Forest edge	Interior	Total
Sampled individuals	800	942	684	2426
Density of individuals (individual ha^{-1})	2667	3140	2280	2696
Dead (%)	5.62	6.68	7.30	6.51
Basal area (m^2 ha^{-1})	8.65	11.71	9.31	29.67
Total families (families ha^{-1})	56	56	53	77
Total species (species ha^{-1})	186	227	198	373
Shannon Diversity (nats ind^{-1})	4.45	4.55	4.62	4.86
Pielou equability	0.87	0.86	0.89	0.84

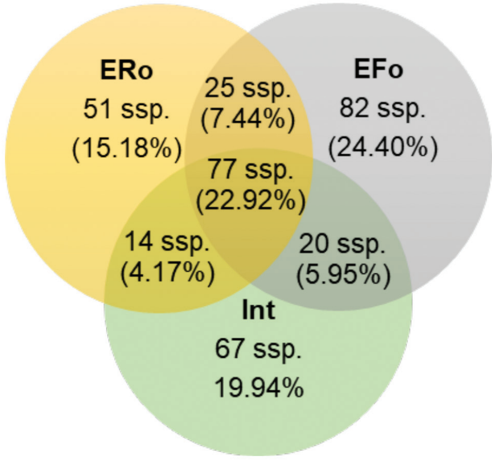

Figure 2 Venn diagram of the species sharing the different environments of the dense ombrophilous lowland forest in the Córrego Grande Biological Reserve
ERo = road edge, EFo = forest edge and Int = interior

The families with the greatest richness in species and morphotypes were Fabaceae (50 species) and Myrtaceae (40 species). The three species which presented the highest importance values (IVs) of the woody stratum for the roadside area were *Astrocaryum aculeatissimum* (11.72%), *Eriotheca macrophylla* (11.51%) and *Eschweilera ovata* (10.72%). For the forest edge, *Protium heptaphyllum* (14.39%) and *Macrolobium latifolium* (12.35%), *Guapira opposita* (12.09%) had the highest IV values. For the interior, *A. aculeatissimum* (13.33%), *Joanesia princeps* (12.39%) and *Virola officinalis* (10.65%) showed the highest IV values (Appendix).

The diametric distribution presented a J-inverted pattern for all areas. The first two classes containing individuals with DBH of 2.5–20.9 cm, consisted 93.0% of the individuals in road edge, 92.2% of the individuals in forest edge and 91.5% of the individuals in interior. It is noteworthy that individuals with a DBH less than 5 cm accounted for approximately 41% (989 individuals) of all sampled specimens. The mean height of the individuals at the roadside was 6.8 m, the forest edge was 8.0 m and inside the forest was 6.2 m. The maximum heights of 17.0 m at the roadside, 50.0 m in the forest edge and 30.0 m inside the forest respectively. The distribution of individuals by hypsometric classes showed that first three classes concentrated 94.1% at the roadside, 83.4% in the forest edge and 93.8% inside the forest of all specimens inventoried. The second hypsometric class (4.3 to 8.4 m) gathered the highest percentages of individuals at 55.7% at the roadside, 45.1% in the forest edge and 42.3% inside the forest (Figure 3).

The Kruskal-Wallis nonparametric test revealed significant differences between the studied environments in relation to the density of the individuals in forest edge and interior

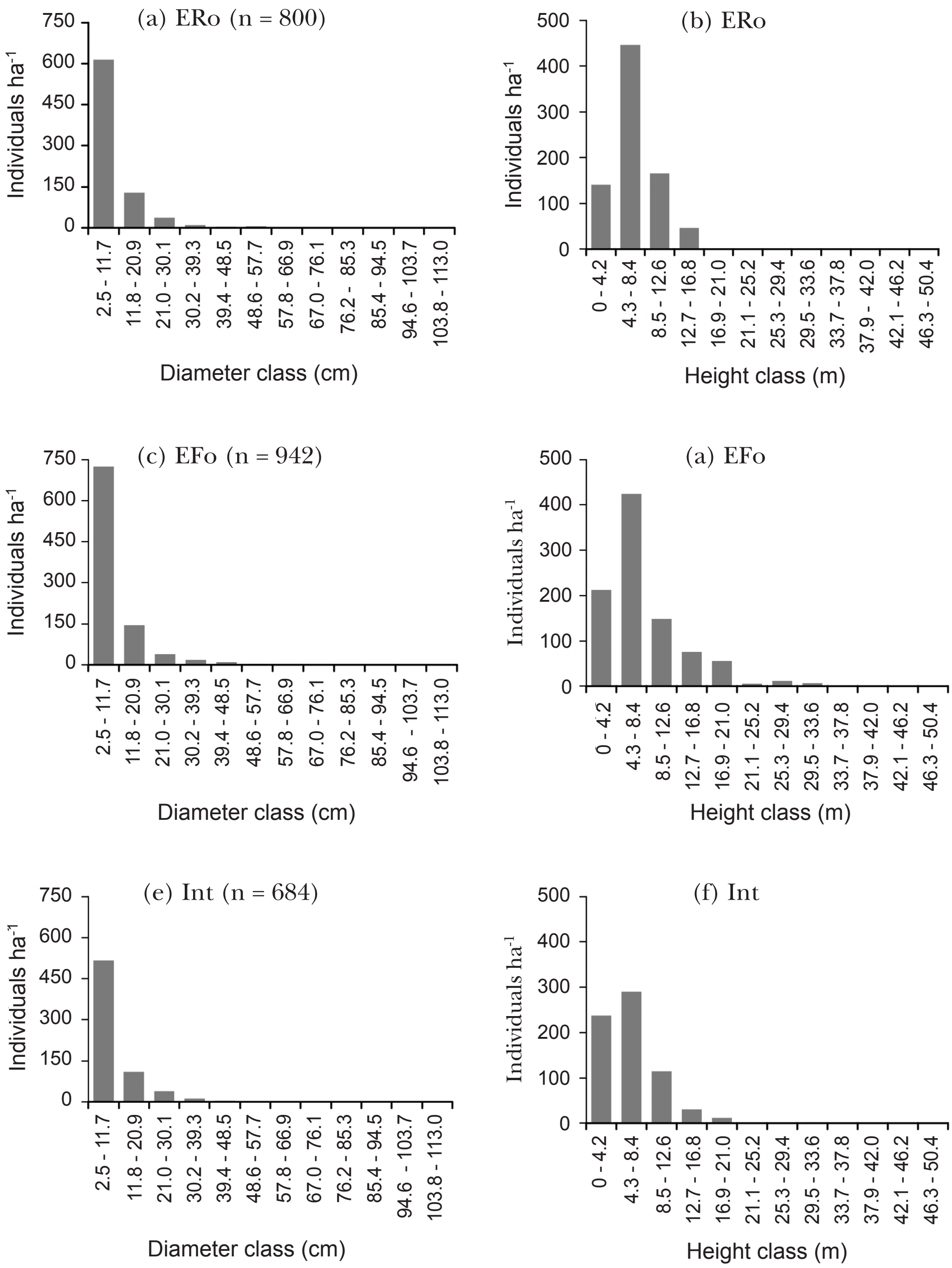

Figure 3 Distribution of individuals of the woody stratum by diameter and height classes at the roadside (ERo), forest edge (EFo) and interior (Int) sampled in remnants of dense ombrophilous lowland forest in the Córrego Grande Biological Reserve

(Kruskal-Wallis = 0.023, $p < 0.05$) and between forest edge and roadside (Kruskal-Wallis = 0.321, $p < 0.05$).

The analysis of a non-metric multidimensional scale revealed the formation of groups with greater similarity of species (Figure 4) showing the composition of the species for the three areas varied significantly between them for the two indices evaluated (ANOSIM: Jaccard R = 0.22, $p < 0.01$, Bray Curtis R = 0.27, $p < 0.01$).

The interior of the remnant forest showed greater diversity of species and differed from the edges of the roadside and the forest based on the number of individuals (Figure 5). In contrast, the forest edge differed from the roadside and the interior of the remnant based on the sample

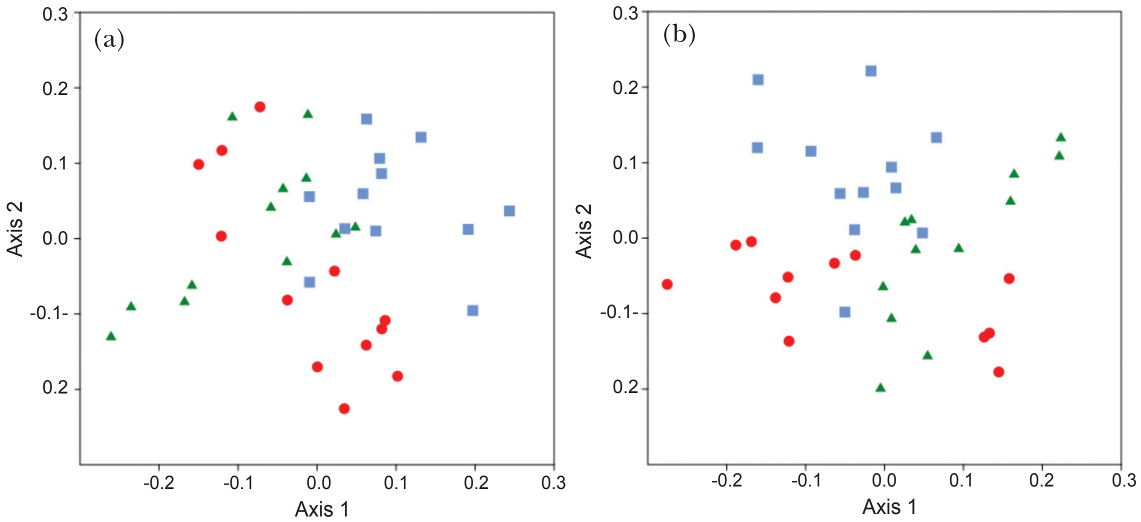

Figure 4 Non-metric multidimensional scale based on species composition among the plots of the three studied environments using ordination by the Jaccard Index (a) and Bray Curtis (b) at Córrego Grande Biological Reserve, Brazil
Circle = roadside, Triangle = forest edge, Square = interior

units, which showed lower diversity of species (Figure 5a and 5b). The forest edge and the inside forest environments showed the highest species richness for the number of individuals (Figure 5c). Similar richness patterns were observed between the inside forest and forest edge environments but there were differences between these environments with the roadside (Figure 5d).

According to the indicator species analysis, three species obtained significantly different distribution ($p < 0.05$) with an indicator value (VI) greater than 50%. *E. ovata* (VI = 57.5%, p-value = 0.0016) was chosen as an indicator of the roadside, while *M. latifolium* (VI = 75.6%, p-value = 0.0004) and *P. heptaphyllum* (VI = 53.3%, p-value = 0.0030) were forest border indicator species.

Vegetation-environment relationship

The two axes of the canonical correspondence analysis explained 56.5% of the variation of species and sampling units as a function of environmental variables (Axis 1 = 33.2%, Axis 2 = 23.3%). The variables humidity and penetration resistance showed strong correlation ($p > 0.5$) with axis 2. Variables such as potassium, sodium and cation exchange capacity also indicated correlation with the axis, where sodium and cation exchange capacity were negatively correlated. The same variables correlated in axis 2 and for axis 1, but with a weaker correlation (Figure 6).

The plots located at the roadside (Rows 1 to 12) presented higher values of cation exchange capacity and sodium but low values for the other variables (Figure 6a). The dominant species in this group were *Astrocaryum aculeatissimum*, *Trichilia lepidota*, *Astronium graveolens* and *Eschweilera ovata*, which were considered indicator species of this environment (Figure 6b). Half of the forest edge sampling units (rows 13 to 24) presented higher values of humidity and penetration resistance with intermediate values of sodium and cation exchange capacity (Figure 6a). Most of the plots located inside the forest were in the central part of the diagram, showing intermediate values for all variables with the exception of Rows 31 and 32 (Figure 6a).

The study showed *E. macrophylla*, *J. princeps* and *Pterocarpus rohrii* were more strongly associated with the variables of humidity and penetration resistance. *Virola officinalis* was associated with higher levels of potassium. On the other hand, *Lacistema robustum*, *Eugenia astringens* and *Tabernaemontana salzmannii* were strongly associated with cation exchange capacity and sodium.

DISCUSSION

Vegetation structure

The results showed that fragmentation was the conditioning factor of the edge effect. It influenced the structure and distribution of plant

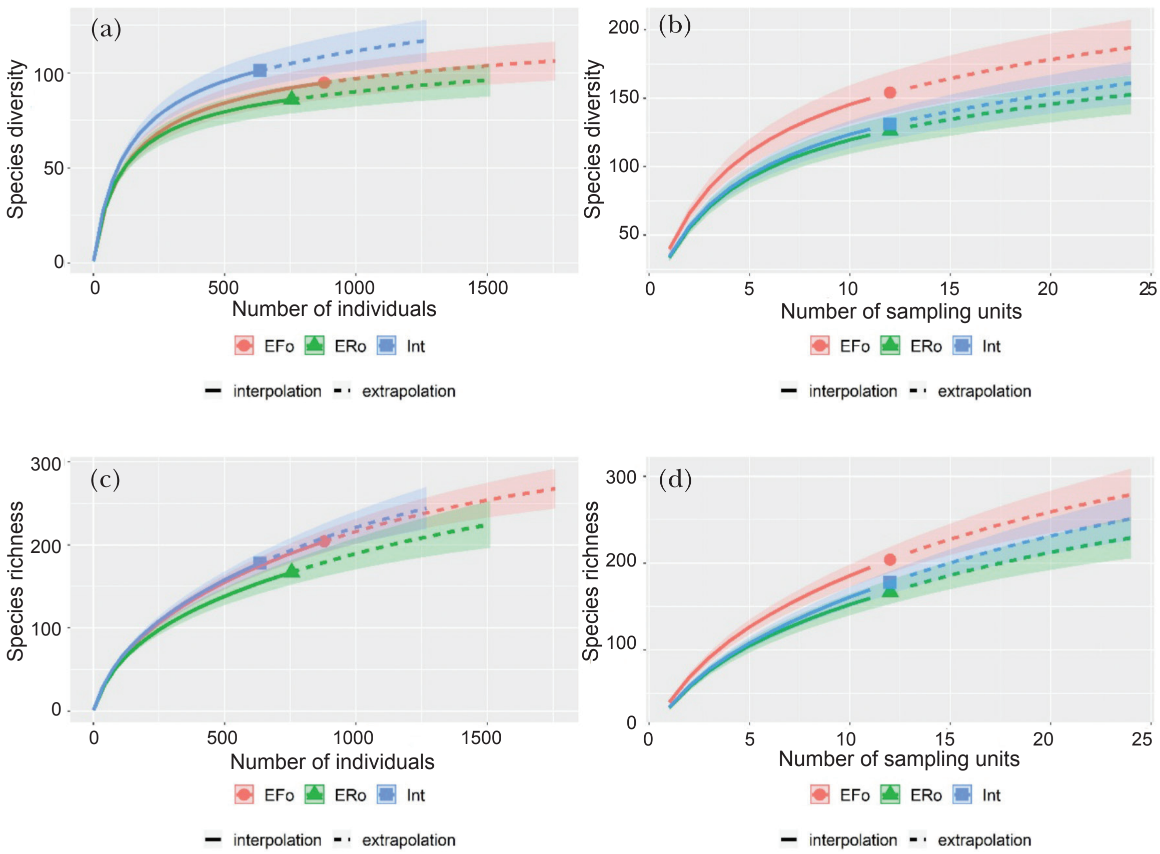

Figure 5 Rarefaction (solid line) and extrapolation curves (dashed lines) based on the number of individuals (a) and (c), sample units (b) and (d), species diversity and species richness for the three different areas sampled at the Córrego Grande Biological Reserve, Brazil.
The rarefaction and extrapolation curves represent mean values and standard deviation with 95% confidence intervals
EFo = forest edge, ERo = roadside and Int = interior

community species and corroborated with the existing literature, where intense edge effects were manifested in the 50 m margins of the forest remnants (Murcia 1995, Dias et al. 2019). This is a pattern commonly observed in forest remnants with distinct perturbation histories. It reinforces the relevance of environmental differences between the edge and interior of forest remnants as predictors for communities of tree species (Pscheidt 2018), which affects the composition of species and vegetation structure (Dias et al. 2019).

The estimated number of species per hectare in this study was 373 species ha^{-1} and near to values observed in other studies conducted in dense ombrophilous forest (Magnago et al. 2014, Saiter & Thomaz 2014). The conditions of which edge environments were subjected to could be the main reason for the high values of diversity and equability found in the studied environments and also shown by the indices and in the rarefaction and extrapolation curves. Such environments were more exposed to external disturbances and generally had a greater diversity and density of species (Fortin 1994).

Matrices comprised of different characteristics have different impacts on the recruitment and establishment of certain plant species (Nascimento & Laurance 2006). Thus, the different types of matrices related to the studied environments such as road and forest stands could influence the establishment and generated different patterns of species composition in the environments (Murcia 1995, Lima-Ribeiro 2008). Thus, the fragments of the surrounding matrix should be managed to minimize the edge effect and to improve connectivity (Ribeiro et al. 2009, Yoshida et al. 2019).

The two edge environments studied showed a higher abundance of individuals when compared to the interior of the remnant where the forest edge showed the highest species

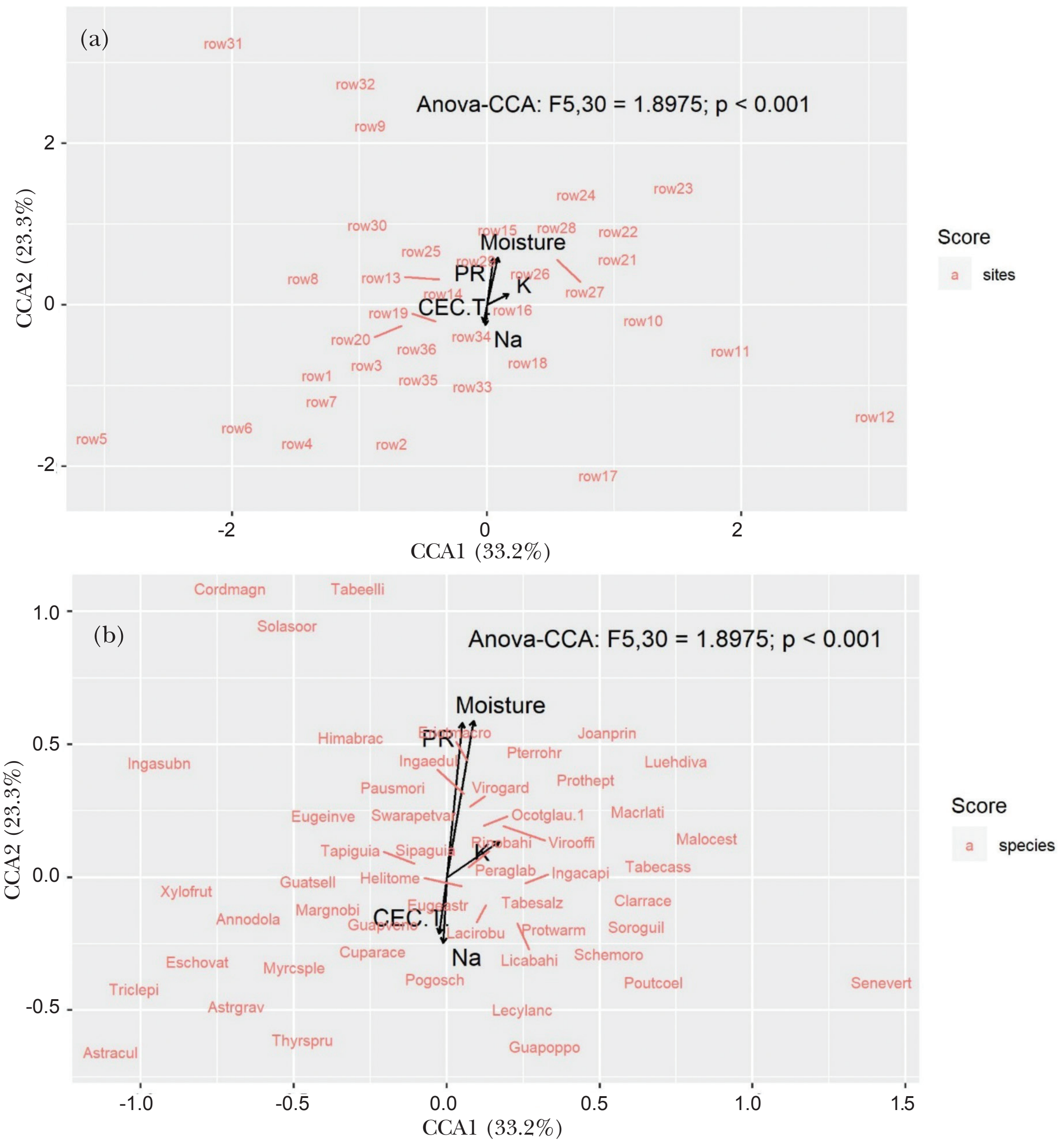

Figure 6 Canonical correspondence analysis (CCA) with the ordination of the 36 sample units (a) and the species of greatest abundance (b) as a function of environmental variables

Annodola = *Annona dolabripetala*, Astracul = *Astrocaryum aculeatissimum*, Astrgrav = *Astronium graveolens*, Clarrace = *Clarisia racemose*, Cordmagn = *Cordia magnoliifolia*, Cuparace = *Cupania racemose*, Eriotmacro = *Eriotheca macrophylla*, Eschovat = *Eschweilera ovata*, Eugeastr = *Eugenia astringens*, Eugeinve = *Eugenia inversa*, Guapoppo = *Guapira opposite*, Guapveno = *Guapira venosa*, Guatsell = *Guatteria sellowiana*, Helitome = *Helicostylis tomentosa*, Himabrac = *Himatanthus bracteatus*, Ingacapi = *Inga capitate*, Ingaedul = *Inga edulis*, Ingasubn = *Inga subnuda*, Joanprin = *Joannesia princeps*, Lacirobu = *Lacistema robustum*, Lecylanc = *Lecythis lanceolate*, Licabahi = *Licaria bahiana*, Luehdiva = *Luehea divaricate*, Macrlati = *Macrolobium latifolium*, Malocest = *Malouetia cestroides*, Margnobi = *Margaritaria nobilis*, Myrcsple = *Myrcia splendens*, Ocotglau = *Ocotea glauca*, Pausmori = *Pausandra morisiana*, Peraglab = *Pera glabrata*; Pogosch = *Pogonophora schomburgkiana*, Poutcoel = *Pouteria coelomatica*, Prothept = *Protium heptaphyllum*, Protwarm = *Protium warmingianum*, Pterrohr = *Pterocarpus rohrii*, Rinobahi = *Rinorea bahiensis*, Schemoro = *Didymopanax morototoni*, Senevert = *Senefeldera verticillate*, Sipaguia = *Siparuna guianensis*, Solasoor = *Solanum sooretamum*, Soroguil = *Sorocea guilleminiana*, Swarapetvar = *Swartzia apetala* var. *apetala*, Tabecass = *Tabebuia cassinoides*, Tabeelli = *Tabebuia elliptica*, Tabesalz = *Tabernaemontana salzmannii*, Tapiguia = *Tapirira guianensis*, Thyrspru = *Thyrsodium spruceanum*, Triclepi = *Trichilia lepidota*, Virogard = *Virola gardneri*, Virooffi = *Virola officinalis*, Xylofrut = *Xylopia frutescens* richness. Approximately 60% of the total species sampled were found in only one of the three environments, which inferred that most species had their specific habitats or were restricted by other habitats. The three environments showed to have unique species. Thus, preservation of the remnant forest is important with the purpose to protect species against extinction due to the different environment conditions in forests with fragmentation situations (Pscheidt et al. 2018). The high concentration of individuals within the first diametric classes revealed the presence of high number of young specimens in the community, suggesting good reproduction rate for new individuals. In this manner, the community achieved self-sustainability as new individuals present in the understory would be able to replace individuals which had already reach maximum maturity (Colonetti et al. 2009). The small number or absence of individuals in the higher diameter classes might be related to mortality caused by the edge effect (Laurance et al. 2000) as well as to the high abundance of small-sized species such as *Tabernaemontana salzmannii*.

The percentage of dead trees at the edges were lower when compared to the interior of the remaining and mostly consisted of small size individuals. Studies conducted in dense ombrophilous forest have shown accelerated mortality of trees in the edge areas, especially in the first years after fragmentation and large trees were the most affected ones (Laurance et al. 2000). In addition, the lower mortality of the species present in the edges was caused by their generalist nature, enabling them to adapt to these edge environment changes caused by the fragmentations.

Astrocaryum aculeatissimum (Family Arecaceae), a tree from the largest indicator value species of the forest edge and a great importance species in the studied remnant forest (Costa et al. 2017), depended on medium and large mammals for its seed dispersal (Zucaratto & Pires 2015). In fragmented forests, these animals were rare or absent, causing reduced distribution of the *A. aculeatissimum* seedlings (Donatti et al. 2009) and resulting in an aggregate spatial distribution of these palm trees (Zucaratto & Pires 2015). In addition, the regrowth capacity of these species also depended on its persistence and survival ability even in the absence of the seed dispersing agents (Bond & Midgley 2001). This partly explained the differences in relationship observed in the density between the forest edge with the interior, the height between the forest edge with the interior and the differences between the forests edges with other environments studied in the remnant forest.

Some of the rainforests in the world consist of secondary forests and their importance will continue to increase (Chazdon 2014, Lohbeck et al. 2016). Therefore, in order to maintain the high species diversity and richness in these regions, conservation efforts should ensure the forest remnants continue to exist, maintain a higher proportion of biodiversity and not subjected to additional fragmentation. In tropical regions, anthropic activities had caused loss of large forest areas, the protection of these areas remained the focal strategy to reduce deforestation and species extinction (Joppa et al. 2008).

The results from this study emphasized the need for site-specific recommendations on the management of the forest rather than generalized recommendations. It was due to the substantial influences of microclimate on the structure of the forest edge. When site-specific managements were in place, only then the microclimate, functioning and biodiversity of the edge of the forest could be conserved on a local scale (Meeussen et al. 2020). Conservation actions beyond the boundaries of these fragments were of paramount importance for the protection of these habitats and the maintenance of biodiversity.

Vegetation-environment relationship

Environmental variables such as moisture, penetration resistance, cation exchange capacity and sodium and potassium levels were the main factors which explained the differences between the studied environments and these parameters determined the composition of the community (Rodrigues et al. 2020). The higher humidity values of the sample units within the forest edge were probably related to the higher presence of clay in the ground (Corrêa Neto et al. 2018) and consequently caused greater resistance to penetration compared to other environments (Mendes et al. 2016).

Some species were concentrated in the centre of the diagram, presenting low canonical values for the two ordination axes and therefore be concluded that these species present greater plasticity (Souza et al. 2017). Unlike these species, *Eschweilera ovata* an indicator species of the roadside which appeared far from the centre of the diagram was classified for tropical forests in the North of the Espírito Santo as late secondary forest species (Jesus & Rolim 2005). However, this species was also found in different successional stages, indicating its potential to adapt to different environments (Magnago et al. 2014).

Previous study showed the microclimate at the forest edge differed from that of the interior of the forest, in addition to other attributes such as physical and chemical soil properties (Pinto et al. 2010). These changes in environmental variables along the sample units probably also promoted high species turnover among the studied environments which was shown with the variation in species composition. The heterogeneity detected supported the different species associations with the different types of environments (Schmitz et al. 2020).

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Appendix Phytosociological parameters of woody strata species at the edge road (ERo), edge forest (EFo) and interior (Int) sampled in the Córrego Grande Biological Reserve

Family / Species	ERo				EFo				Int			
	N	RD	RDo	IV	N	RD	RDo	IV	N	RD	RDo	IV
Anacardiaceae												
Astronium graveolens Jacq.	15	1.99	0.28	3.02	8	0.91	0.64	2.39	24	3.79	0.62	6.11
Astronium sp.	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Tapirira guianensis Aubl.	6	0.79	2.65	4.69	2	0.23	0.55	1.31	4	0.63	1.24	2.59
Thyrsodium spruceanum Benth.	15	1.99	1.39	5.12	4	0.46	0.27	1.35	13	2.05	1.39	4.90
Annonaceae												
Annona acutiflora Mart.	7	0.93	0.44	2.37	1	0.11	0.01	0.33	2	0.32	0.06	0.86
Annona dolabripetala Raddi	14	1.85	3.24	6.83	9	1.02	3.61	5.68	16	2.52	3.72	7.94
Annonaceae sp.1	-	-	-	-	1	0.11	0.00	0.32	-	-	-	-
Annonaceae sp.2	-	-	-	-	-	-	-	-	1	0.16	0.06	0.46
Annonaceae sp.3	-	-	-	-	-	-	-	-	1	0.16	0.32	0.72
Annonaceae sp.4	-	-	-	-	-	-	-	-	2	0.32	1.61	2.17
Duguetia chrysocarpa Maas	-	-	-	-	3	0.34	0.08	0.84	4	0.63	0.25	1.61
Guatteria australis A.St.-Hil.	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Guatteria cf. australis A.St.-Hil.	-	-	-	-	-	-	-	-	1	0.16	0.01	0.41
Guatteria oligocarpa Mart.	2	0.26	0.09	0.86	2	0.23	0.16	0.81	2	0.32	0.28	1.08
Guatteria pogonopus Mart.	2	0.26	0.13	0.89	-	-	-	-	-	-	-	-
Guatteria sellowiana Schltdl.	5	0.66	0.39	1.79	16	1.82	2.49	5.36	11	1.73	1.60	5.27
Oxandra espintana (Spruce ex Benth.) Baill.	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Pseudoxandra spiritus-sancti Maas	3	0.39	0.11	1.26	5	0.57	0.42	1.62	1	0.16	0.01	0.42
Xylopia frutescens Aubl.	13	1.72	2.65	5.86	10	1.14	1.16	3.14	3	0.47	0.10	1.30
Xylopia ochrantha Mart.	1	0.13	0.02	0.39	-	-	-	-	-	-	-	-
Apocynaceae												
Aspidosperma cf. illustre (Vell.) Kuhlm. & Pirajá	7	0.93	0.07	1.75	-	-	-	-	-	-	-	-
Aspidosperma cylindrocarpon Müll.Arg.	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Aspidosperma desmanthum Benth. ex Müll.Arg.	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Aspidosperma illustre Vell.) Kuhlm. & Pirajá	-	-	-	-	1	0.11	0.13	0.34	-	-	-	-
Aspidosperma sp.1	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Aspidosperma sp.2	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Himatanthus bracteatus (A. DC.) Woodson	7	0.93	0.23	2.39	2	0.23	0.10	0.54	9	1.42	1.38	3.53
Malouetia cestroides (Nees ex Mart.) Müll.Arg.	2	0.26	0.32	1.08	10	1.14	0.77	2.96	4	0.63	0.17	1.78
Rauvolfia capixabae I.Koch & Kin.-Gouv.	-	-	-	-	-	-	-	-	1	0.16	0.02	0.42
Tabernaemontana salzmannii A.DC.	12	1.59	0.33	3.66	25	2.84	0.49	5.22	6	0.94	0.15	2.31

Appendix *continue*

Family / Species	ERo				EFo				Int			
	N	RD	RDo	IV	N	RD	RDo	IV	N	RD	RDo	IV
Araliaceae												
Dendropanax sp.	-	-	-	-	-	-	-	-	1	0.16	0.07	0.47
Didymopanax morototoni (Aubl.) Decne. & Planch.	26	3.44	3.28	8.22	5	0.57	2.09	3.49	1	0.16	0.48	0.88
Arecaceae												
Arecaceae sp.	-	-	-	-	-	-	-	-	1	0.16	0.29	0.69
Astrocaryum aculeatissimum (Schott) Burret	18	2.38	7.34	11.72	7	0.79	1.02	2.66	3	0.47	12.12	13.33
Asteraceae												
Piptocarpha oblonga (Gardner) Baker	5	0.66	0.09	1.26	-	-	-	-	-	-	-	-
Bignoniaceae												
Bignoniaceae sp.	1	0.13	0.09	0.47	1	0.11	0.09	0.41	-	-	-	-
Sparattosperma leucanthum (Vell.) K.Schum.	3	0.39	0.07	1.22	1	0.11	0.02	0.34	1	0.16	0.01	0.41
Tabebuia cassinoides (Lam.) DC.	5	0.66	0.19	1.59	6	0.68	0.69	1.99	8	1.26	0.38	3.10
Tabebuia elliptica (DC.) Sandwith	23	3.04	1.63	5.67	7	0.79	0.11	2.37	10	1.58	0.45	3.24
Tabebuia roseoalba (Ridl.) Sandwith	1	0.13	0.03	0.41	-	-	-	-	-	-	-	-
Boraginaceae												
Cordia magnoliifolia Cham.	4	0.53	0.06	1.59	3	0.34	0.04	1.00	16	2.52	0.35	4.33
Cordia trichoclada DC.	-	-	-	-	1	0.11	0.03	0.35	1	0.16	0.01	0.41
Burseraceae												
Burseraceae sp.	-	-	-	-	-	-	-	-	1	0.16	0.01	0.41
Protium aracouchini (Aubl.) Marchand	-	-	-	-	3	0.34	0.05	0.81	-	-	-	-
Protium atlanticum (Daly) Byng & Christenh.	1	0.13	0.01	0.38	-	-	-	-	-	-	-	-
Protium cf. catuaba (Soares da Cunha) Daly & P.Fine	-	-	-	-	1	0.11	0.75	1.07	-	-	-	-
Protium heptaphyllum (Aubl.) Marchand	10	1.32	1.07	3.89	54	6.14	6.37	14.39	12	1.89	1.79	4.90
Protium sp.	1	0.13	0.05	0.43	2	0.23	0.02	0.46	2	0.32	0.05	0.84
Protium warmingianum Marchand	15	1.98	0.98	4.21	14	1.59	0.69	3.53	4	0.63	1.16	2.52
Trattinnickia mensalis Daly	-	-	-	-	1	0.11	0.18	0.49	-	-	-	-
Caricaceae												
Jacaratia heptaphylla (Vell.) A.DC.	-	-	-	-	2	0.23	0.65	1.29	1	0.16	0.03	0.52
Caryocaraceae												
Caryocar edule Casar.	2	0.26	0.02	0.79	-	-	-	-	2	0.32	0.37	1.17

Appendix *continue*

Family / Species	ERo				EFo				Int			
	N	RD	RDo	IV	N	RD	RDo	IV	N	RD	RDo	IV
Chrysobalanaceae												
Couepia schottii Fritsch	3	0.39	0.03	1.18	1	0.11	0.09	0.42	2	0.32	0.50	1.30
Exellodendron gracile (Kuhlm.) Prance	1	0.13	0.01	0.39	2	0.23	0.07	0.72	1	0.16	0.02	0.40
Hirtella sp.	-	-	-	-	-	-	-	-	1	0.16	0.05	0.45
Leptobalanus octandrus (Hoffmanns. ex Roem. & Schult.) Sothers & Prance	1	0.13	0.26	0.64	-	-	-	-	-	-	-	-
Licania heteromorpha Benth.	-	-	-	-	-	-	-	-	2	0.32	0.12	0.92
Licania heteromorpha Benth. var. *heteromorpha*	2	0.26	0.04	0.56	-	-	-	-	3	0.47	0.13	1.33
Licania kunthiana Hook.f.	5	0.66	0.23	1.89	2	0.23	0.96	1.61	1	0.16	3.72	4.12
Licania sp.	2	0.26	0.03	0.79	-	-	-	-	-	-	-	-
Parinari excelsa Sabine	1	0.13	0.34	0.71	2	0.23	0.04	0.69	-	-	-	-
Parinari parvifolia Sandwith	2	0.26	0.09	0.61	-	-	-	-	-	-	-	-
Clusiaceae												
Clusiaceae sp.	-	-	-	-	1	0.11	0.05	0.37	-	-	-	-
Garcinia brasiliensis Mart.	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Combretaceae												
Terminalia kleinii (Exell) Gere & Boatwr.	2	0.26	0.19	0.71	-	-	-	-	-	-	-	-
Cyperaceae												
Cyperus sp.	3	0.39	0.17	1.31	-	-	-	-	2	0.32	0.03	0.59
Dichapetalaceae												
Stephanopodium blanchetianum Baill.	-	-	-	-	2	0.23	0.15	0.59	1	0.16	0.01	0.41
Elaeocarpaceae												
Sloanea sinemariensis Aubl.	3	0.39	0.49	1.63	1	0.11	0.01	0.33	-	-	-	-
Euphorbiaceae												
Aparisthmium cordatum (A.Juss.) Baill.	5	0.66	0.12	1.78	1	0.11	0.01	0.33	1	0.16	0.04	0.44
Euphorbiaceae sp.	-	-	-	-	-	-	-	-	1	0.16	0.33	0.73
Joannesia princeps Vell.	4	0.53	3.13	4.16	11	1.25	3.17	5.05	16	2.52	8.89	12.39
Mabea fistulifera Mart.	-	-	-	-	-	-	-	-	9	1.42	1.80	3.71
Maprounea guianensis Aubl.	2	0.26	0.12	0.88	1	0.11	0.09	0.41	5	0.79	0.43	2.19
Pausandra morisiana (Casar.) Radlk.	-	-	-	-	4	0.46	0.04	0.71	10	1.58	0.12	3.39
Sapium glandulosum (L.) Morong	-	-	-	-	-	-	-	-	1	0.16	0.32	0.72
Senefeldera verticillata (Vell.) Croizat	45	5.96	2.67	9.37	-	-	-	-	-	-	-	-

Appendix *continue*

Family / Species	ERo				EFo				Int			
	N	RD	RDo	IV	N	RD	RDo	IV	N	RD	RDo	IV
Fabaceae												
Abarema cochliacarpos (Gomes) Barneby & J.W.Grimes	-	-	-	-	-	-	-	-	2	0.32	0.15	0.71
Albizia pedicellaris (DC.) L.Rico	-	-	-	-	-	-	-	-	1	0.16	0.69	1.09
Andira fraxinifolia Benth.	1	0.13	0.04	0.42	-	-	-	-	-	-	-	-
Andira ormosioides Benth.	2	0.26	0.02	0.78	-	-	-	-	1	0.16	0.06	0.46
Copaifera lucens Dwyer	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Dialium guianense (Aubl.) Sandwith	-	-	-	-	8	0.91	1.41	3.16	1	0.16	0.22	0.62
Dimorphandra jorgei M.F.Silva	-	-	-	-	-	-	-	-	1	0.16	0.65	1.05
Fabaceae sp.1	1	0.13	0.23	0.61	1	0.11	0.19	0.51	-	-	-	-
Fabaceae sp.2	-	-	-	-	1	0.11	1.21	1.53	-	-	-	-
Fabaceae sp.3	-	-	-	-	1	0.11	0.22	0.54	1	0.16	0.41	0.81
Fabaceae sp.4	1	0.13	0.01	0.39	1	0.11	0.01	0.33	1	0.16	0.11	0.51
Fabaceae sp.5	-	-	-	-	-	-	-	-	3	0.47	0.32	1.52
Inga aff. cylindrica (Vell.) Mart.	-	-	-	-	2	0.22	0.05	0.49	-	-	-	-
Inga capitata Desv.	1	0.13	0.01	0.39	3	0.34	0.39	1.15	7	1.10	1.77	3.85
Inga cf. exfoliata T.D.Penn. & F.C.P.García	1	0.13	0.04	0.43	-	-	-	-	-	-	-	-
Inga edulis Mart.	-	-	-	-	8	0.91	0.28	2.23	5	0.79	1.09	2.85
Inga flagelliformis (Vell.) Mart.	1	0.13	0.95	1.33	-	-	-	-	4	0.63	0.65	2.01
Inga lanceifolia Benth.	2	0.26	0.11	0.87	3	0.34	0.05	1.02	4	0.63	0.05	1.40
Inga laurina (Sw.) Willd.	-	-	-	-	-	-	-	-	1	0.16	0.87	1.27
Inga sessilis (Vell.) Mart.	-	-	-	-	-	-	-	-	1	0.16	0.05	0.46
Inga sp.1	-	-	-	-	1	0.11	0.45	0.77	2	0.32	0.07	0.87
Inga sp.2	-	-	-	-	-	-	-	-	1	0.16	0.02	0.42
Inga subnuda Salzm. ex Benth.	16	2.12	3.26	7.12	5	0.57	0.92	2.12	15	2.37	2.02	5.85
Lonchocarpus cultratus (Vell.) A.M.G.Azevedo & H.C.Lima	4	0.53	0.51	1.29	5	0.57	5.34	6.75	-	-	-	-
Lonchocarpus sp.	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Machaerium cf. lanceolatum (Vell.) J.F.Macbr.	-	-	-	-	-	-	-	-	1	0.16	0.01	0.41
Machaerium condensatum Kuhlm. & Hoehne	-	-	-	-	-	-	-	-	3	0.47	0.11	1.07
Machaerium sp.	1	0.13	0.32	0.70	-	-	-	-	1	0.16	0.01	0.44
Macrolobium latifolium Vogel	6	0.79	1.57	3.36	61	6.94	3.11	12.35	7	1.10	0.76	3.56
Melanoxylon brauna Schott	-	-	-	-	1	0.11	0.04	0.36	-	-	-	-
Parapiptadenia pterosperma (Benth.) Brenan	-	-	-	-	1	0.11	0.02	0.34	-	-	-	-
Parapiptadenia sp.1	1	0.13	0.02	0.39	1	0.11	0.15	0.47	-	-	-	-
Parapiptadenia sp.2	-	-	-	-	4	0.46	2.76	3.84	1	0.16	0.16	0.56
Platymiscium floribundum Vogel	-	-	-	-	-	-	-	-	1	0.16	0.04	0.44

Appendix *continue*

Family / Species	ERo				EFo				Int			
	N	RD	RDo	IV	N	RD	RDo	IV	N	RD	RDo	IV
Pseudopiptadenia contorta (DC.) G.P.Lewis & M.P.Lima	1	0.13	0.24	1.31	-	-	-	-	-	-	-	-
Pterocarpus rohrii Vahl	-	-	-	-	16	1.82	0.60	3.89	13	2.05	1.34	5.09
Senna affinis (Benth.) H.S.Irwin & Barneby	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Swartzia acutifolia Vogel	-	-	-	-	3	0.34	0.07	0.83	3	0.47	0.13	1.20
Swartzia apetala Raddi	1	0.13	0.01	0.39	1	0.11	0.01	0.33	-	-	-	-
Swartzia apetala Raddi var. *apetala*	10	1.32	0.33	3.15	3	0.34	0.04	1.01	4	0.63	0.08	1.68
Swartzia apetala var. *glabra* (Vogel) R.S.Cowan	1	0.13	0.02	0.40	-	-	-	-	-	-	-	-
Swartzia cf. oblata R.S.Cowan	-	-	-	-	1	0.11	0.03	0.35	-	-	-	-
Swartzia micrantha R.S.Cowan	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Swartzia simplex var. *continentalis* Urb.	-	-	-	-	1	0.11	0.03	0.35	-	-	-	-
Swartzia sp.	-	-	-	-	1	0.11	0.01	0.34	-	-	-	-
Vatairea sp.1	-	-	-	-	2	0.22	0.34	0.98	-	-	-	-
Vatairea sp.2	-	-	-	-	1	0.11	0.04	0.36	-	-	-	-
Vataireopsis araroba (Aguiar) Ducke	1	0.13	0.01	0.39	-	-	-	-	1	0.16	0.05	0.45
Zollernia ilicifolia (Brongn.) Vogel	-	-	-	-	3	0.34	0.05	1.01	-	-	-	-
Zollernia splendens Wied-Neuw. & Nees	-	-	-	-	2	0.22	0.19	0.83	-	-	-	-
Hernandiaceae												
Sparattanthelium sp.	1	0.13	0.17	0.54	1	0.11	0.07	0.39	-	-	-	-
Sparattanthelium tupiniquinorum Mart.	-	-	-	-	1	0.11	0.02	0.34	-	-	-	-
Humiriaceae												
Humiriastrum dentatum (Casar.) Cuatrec.	4	0.53	0.05	1.33	-	-	-	-	-	-	-	-
Hypericaceae												
Vismia macrophylla Kunth	-	-	-	-	-	-	-	-	3	0.47	0.55	1.51
Lacistemataceae												
Lacistema robustum Schnizl.	4	0.53	0.21	1.48	6	0.68	0.73	2.45	6	0.95	0.36	2.52
Lauraceae												
Aniba canelilla (Kunth) Mez	1	0.13	0.05	0.43	-	-	-	-	1	0.16	0.74	1.14
Aniba cf. intermedia (Meisn.) Mez	-	-	-	-	-	-	-	-	1	0.16	0.14	0.54
Aniba firmula (Nees & Mart.) Mez	1	0.13	0.15	0.53	3	0.34	0.41	1.38	2	0.32	0.08	0.88
Licaria bahiana Kurz	7	0.93	0.79	2.72	8	0.91	0.55	2.71	7	1.10	0.65	3.22
Licaria sp.	-	-	-	-	1	0.11	0.04	0.36	-	-	-	-
Nectandra membranacea (Sw.) Griseb.	-	-	-	-	-	-	-	-	1	0.16	0.07	0.47
Ocotea argentea Mez	-	-	-	-	-	-	-	-	1	0.16	0.01	0.41

Appendix *continue*

Family / Species	ERo				EFo				Int			
	N	RD	RDo	IV	N	RD	RDo	IV	N	RD	RDo	IV
Ocotea cf. glauca (Nees & Mart.) Mez	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Ocotea cf. kostermanniana Vattimo-Gil	-	-	-	-	-	-	-	-	1	0.16	0.01	0.41
Ocotea ciliata L.C.S.Assis & Mello-Silva	1	0.13	0.11	0.49	1	0.11	0.01	0.33	2	0.32	0.50	1.06
Ocotea confertiflora (Meisn.) Mez	-	-	-	-	1	0.11	0.09	0.41	-	-	-	-
Ocotea divaricata (Nees) Mez	-	-	-	-	-	-	-	-	1	0.16	0.07	0.47
Ocotea glauca (Nees & Mart.) Mez	1	0.13	0.01	0.39	5	0.57	0.08	1.49	6	0.94	0.17	2.57
Ocotea lancifolia (Schott) Mez	-	-	-	-	1	0.11	0.05	0.37	4	0.63	0.27	1.63
Ocotea nutans (Nees) Mez	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Ocotea pluridomatiata A.Quinet	-	-	-	-	1	0.11	0.01	0.33	1	0.16	0.04	0.45
Ocotea sp.1	2	0.26	0.17	0.94	-	-	-	-	1	0.16	0.01	0.42
Ocotea sp.2	-	-	-	-	-	-	-	-	1	0.16	0.07	0.47
Ocotea velutina (Nees) Rohwer	-	-	-	-	-	-	-	-	2	0.32	1.22	1.78
Persea sp.	-	-	-	-	-	-	-	-	1	0.16	0.03	0.43
Rhodostemonodaphne capixabensis J.B. Baitello & Coe-Teix.	-	-	-	-	-	-	-	-	4	0.63	2.91	4.03
Lecythidaceae												
Couratari macrosperma A.C.Sm.	2	0.26	0.21	0.73	-	-	-	-	3	0.47	0.09	1.05
Eschweilera ovata (Cambess.) Mart. ex Miers	32	4.24	3.75	10.73	16	1.82	3.02	6.09	3	0.47	0.15	1.35
Lecythis lanceolata Poir.	6	0.79	0.20	2.49	7	0.79	0.23	2.08	5	0.79	0.07	1.83
Lecythis lurida (Miers) S.A.Mori	-	-	-	-	1	0.11	0.16	0.48	-	-	-	-
Malpighiaceae												
Byrsonima sericea DC.	10	1.32	1.08	6.48	-	-	-	-	-	-	-	-
Byrsonima stipulacea A.Juss.	3	0.39	0.35	2.24	1	0.11	0.13	0.45	1	0.16	0.02	0.42
Niedenzuella sp.	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Malpighiaceae sp.	-	-	-	-	-	-	-	-	1	0.16	0.14	0.54
Malvaceae												
Eriotheca macrophylla (K.Schum.) A.Robyns	22	2.91	6.85	11.51	20	2.28	1.88	5.83	15	2.37	2.35	6.41
Hydrogaster trinervis Kuhlm.	3	0.39	1.18	2.32	3	0.34	0.46	1.43	-	-	-	-
Luehea divaricate Mart.	3	0.39	0.36	1.25	15	1.71	0.56	3.11	2	0.32	0.08	0.88
Malvaceae sp.	1	0.13	2.40	2.78	-	-	-	-	-	-	-	-
Pachira endecaphylla (Vell.) Carv.-Sobr.	1	0.13	0.29	0.67	5	0.57	0.11	1.09	2	0.32	1.93	2.73
Pavonia calyculosa A.St.-Hil. & Naudin	-	-	-	-	7	0.79	0.17	1.59	-	-	-	-
Sterculia apetala (Jacq.) H.Karst.	1	0.13	0.51	0.89	6	0.68	1.71	3.65	-	-	-	-

Appendix *continue*

Family / Species	ERo				EFo				Int			
	N	RD	RDo	IV	N	RD	RDo	IV	N	RD	RDo	IV
Melastomataceae												
Miconia cinnamomifolia (DC.) Naudin	2	0.26	0.66	1.42	1	0.11	0.02	0.34	-	-	-	-
Miconia splendens (Sw.) Griseb.	-	-	-	-	2	0.23	0.09	0.74	-	-	-	-
Mouriri arborea Gardner	-	-	-	-	3	0.34	0.13	1.09	-	-	-	-
Meliaceae												
Meliaceae sp.	-	-	-	-	-	-	-	-	1	0.16	0.03	0.43
Trichilia elegans A.Juss.	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Trichilia lepidota Mart.	7	0.93	2.44	4.86	2	0.23	0.03	0.68	2	0.32	1.82	2.62
Trichilia sp.	-	-	-	-	1	0.11	0.06	0.48	1	0.16	0.39	0.79
Metteniusaceae												
Emmotum affine Miers	3	0.39	0.19	1.09	1	0.11	0.16	0.48	-	-	-	-
Emmotum nitens (Benth.) Miers	2	0.26	0.57	1.09	7	0.79	1.24	2.88	-	-	-	-
Monimiaceae												
Macrotorus utriculatus (Mart.) Perkins	1	0.13	0.02	0.39	-	-	-	-	-	-	-	-
Mollinedia lamprophylla Perkins	-	-	-	-	1	0.11	0.24	0.56	-	-	-	-
Mollinedia sp.	1	0.13	0.13	0.51	-	-	-	-	-	-	-	-
Moraceae												
Brosimum rubescens Taub.	1	0.13	2.78	3.16	2	0.23	1.77	2.41	-	-	-	-
Clarisia racemose Ruiz & Pav.	5	0.66	0.15	1.56	2	0.23	0.04	0.69	4	0.63	0.09	1.69
Ficus trigona L.f.	2	0.26	0.21	0.72	-	-	-	-	-	-	-	-
Helicostylis tomentosa (Poepp. & Endl.) Rusby	25	3.31	0.88	6.18	26	2.96	2.68	7.73	5	0.79	0.26	2.02
Naucleopsis oblongifolia (Kuhlm.) Carauta	-	-	-	-	-	-	-	-	2	0.32	0.28	0.83
Sorocea guilleminiana Gaudich.	9	1.19	0.65	3.09	6	0.68	0.07	1.79	3	0.47	0.11	1.07
Myristicaceae												
Virola gardneri (A.DC.) Warb.	1	0.13	0.03	0.41	6	0.68	0.08	1.82	8	1.26	0.41	2.88
Virola officinalis Warb.	14	1.85	1.40	4.25	10	1.14	0.49	2.88	20	3.15	5.79	10.65
Myrtaceae												
Myrcia loranthifolia (DC.) G.P.Burton & E.Lucas	-	-	-	-	4	0.46	0.09	1.17	-	-	-	-
Myrcia neoclusiifolia A.R.Lourenço & E.Lucas	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Calyptranthes sp.1	-	-	-	-	2	0.66	0.01	0.66	-	-	-	-
Calyptranthes sp.2	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Campomanesia lineatifolia Ruiz & Pav.	-	-	-	-	1	0.11	0.09	0.41	-	-	-	-
Campomanesia sp.1	-	-	-	-	1	0.11	0.01	0.34	-	-	-	-
Campomanesia sp.2	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-

Appendix *continue*

Family / Species	ERo				EFo				Int			
	N	RD	RDo	IV	N	RD	RDo	IV	N	RD	RDo	IV
Eugenia astringens Cambess.	4	0.52	0.16	1.69	11	1.25	0.19	2.69	4	0.63	0.08	1.44
Eugenia bahiensis DC.	3	0.39	0.03	1.17	3	0.34	0.09	1.06	-	-	-	-
Eugenia cf. astringens Cambess.	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Eugenia cf. punicifolia (Kunth) DC.	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Eugenia inversa Sobral	9	1.19	0.43	3.12	18	2.05	0.24	3.54	11	1.73	0.88	4.07
Eugenia pisiformis Cambess.	1	0.13	0.02	0.40	3	0.34	0.05	1.02	1	0.16	0.03	0.43
Eugenia prasina O.Berg	-	-	-	-	1	0.11	0.03	0.36	-	-	-	-
Eugenia pruinosa D.Legrand	-	-	-	-	2	0.23	0.02	0.66	-	-	-	-
Eugenia punicifolia (Kunth) DC.	1	0.13	0.02	0.40	3	0.34	0.04	1.01	1	0.16	0.51	0.91
Eugenia zuccarinii O.Berg	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Eugenia sp.1	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Eugenia sp.2	-	-	-	-	1	0.11	0.02	0.35	-	-	-	-
Eugenia sp.3	-	-	-	-	-	-	-	-	1	0.16	0.01	0.41
Eugenia sp.4	-	-	-	-	-	-	-	-	1	0.16	0.01	0.42
Eugenia sp.5	-	-	-	-	-	-	-	-	1	0.16	0.01	0.41
Eugenia umbellata Spreng.	1	0.13	0.05	0.43	-	-	-	-	2	0.32	0.02	0.82
Myrcia guianensis (Aubl.) DC	-	-	-	-	-	-	-	-	1	0.16	0.04	0.44
Myrcia isaiana G.M.Barroso & Peixoto	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Myrcia sp.1	-	-	-	-	1	0.11	0.04	0.36	-	-	-	-
Myrcia sp.2	-	-	-	-	1	0.11	0.01	0.33	1	0.16	0.11	0.51
Myrcia splendens (Sw.) DC.	9	1.19	1.91	4.09	1	0.11	0.10	0.42	1	0.16	0.16	0.56
Myrcia sucrei (G. M. Barroso & Peixoto) E. Lucas & C. E. Wilson	1	0.13	0.01	0.39	1	0.11	0.06	0.38	-	-	-	-
Myrcia vittoriana Kiaersk.	3	0.39	0.07	1.21	2	0.23	0.04	0.68	1	0.16	0.01	0.41
Myrciaria ferruginea O.Berg	-	-	-	-	2	0.23	0.24	0.88	-	-	-	-
Myrciaria sp.	-	-	-	-	-	-	-	-	1	0.16	0.00	0.42
Myrciaria strigipes O.Berg	8	1.06	0.17	1.72	-	-	-	-	-	-	-	-
Myrtaceae sp.1	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Myrtaceae sp.2	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Myrtaceae sp.3	-	-	-	-	1	0.11	0.00	0.33	-	-	-	-
Myrtaceae sp.4	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Myrtaceae sp.5	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Myrtaceae sp.6	-	-	-	-	-	-	-	-	2	0.32	0.03	0.59
Plinia sp.	1	0.13	0.02	0.40	-	-	-	-	-	-	-	-

Appendix *continue*

Family / Species	ERo				EFo				Int			
	N	RD	RDo	IV	N	RD	RDo	IV	N	RD	RDo	IV
Nyctaginaceae												
Guapira cf. venosa (Choisy) Lundell	1	0.13	0.02	0.40	-	-	-	-	-	-	-	-
Guapira hirsute (Choisy) Lundell	1	0.13	0.00	0.38	3	0.34	0.10	0.86	3	0.47	0.17	1.37
Guapira nítida (Mart. ex J.A.Schmidt) Lundell	4	0.53	0.10	1.37	-	-	-	-	2	0.32	0.02	0.58
Guapira opposite (Vell.) Reitz	28	3.71	1.76	7.21	53	6.03	4.81	12.09	18	2.84	3.13	7.66
Guapira venosa (Choisy) Lundell	7	0.93	0.53	2.45	12	1.37	0.64	3.27	5	0.79	0.19	1.22
Ochnaceae												
Ouratea cf. multiflora (Pohl) Engl.	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Ouratea cuspidate (A.St.-Hil.) Engl.	-	-	-	-	3	0.34	0.03	0.99	-	-	-	-
Ouratea castaneifolia (DC.) Engl.	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Olacaceae												
Heisteria perianthomega (Vell.) Sleumer	1	0.13	0.01	0.39	1	0.11	1.01	1.34	-	-	-	-
Heisteria sp.	-	-	-	-	-	-	-	-	1	0.16	0.04	0.44
Peraceae												
Pera anisotricha Müll. Arg.	1	0.13	0.03	0.41	6	0.68	0.24	1.76	2	0.32	0.02	0.82
Pera cf. glabrata (Schott) Baill.	-	-	-	-	2	0.23	0.21	0.65	-	-	-	-
Pera glabrata (Schott) Baill.	3	0.39	0.09	1.23	12	1.37	0.38	2.79	9	1.42	1.05	4.17
Pera sp.1	1	0.13	0.31	0.69	-	-	-	-	-	-	-	-
Pera sp.2	1	0.13	0.10	0.49	-	-	-	-	1	0.16	1.13	1.53
Pera sp.3	-	-	-	-	1	0.11	0.16	0.48	-	-	-	-
Pogonophora schomburgkiana Miers ex Benth.	27	3.57	1.31	6.63	26	2.96	0.88	5.09	25	3.94	1.18	7.31
Phyllanthaceae												
Hyeronima oblonga (Tul.) Müll.Arg.	1	0.13	0.10	0.49	2	0.23	0.02	0.67	2	0.32	0.29	1.09
Margaritaria nobilis L.f.	6	0.79	1.53	3.57	4	0.46	0.51	1.80	6	0.94	0.68	2.36
Picramniaceae												
Picramnia ciliata Mart.	3	0.39	0.03	0.93	3	0.34	0.02	0.78	1	0.16	0.01	0.41
Polygalaceae												
Acanthocladus pulcherrimus (Kuhlm.) J.F.B.Pastore & D.B.O.S.Cardoso	2	0.26	0.99	1.76	-	-	-	-	-	-	-	-
Polygonaceae												
Coccoloba cf. alnifolia Casar.	-	-	-	-	1	0.11	0.01	0.34	-	-	-	-
Primulaceae												
Myrsine sp.	-	-	-	-	2	0.23	0.46	0.89	-	-	-	-

Appendix *continue*

Family / Species	ERo				EFo				Int			
	N	RD	RDo	IV	N	RD	RDo	IV	N	RD	RDo	IV
Quiinaceae												
Quiina glaziovii Engl.	-	-	-	-	2	0.23	0.07	0.51	-	-	-	-
Rubiaceae												
Amaioua intermedia Mart. ex Schult. & Schult.f.	4	0.53	0.09	1.37	1	0.11	0.02	0.34	-	-	-	-
Eumachia cephalantha (Müll. Arg.) Delprete & J.H. Kirkbr.	5	0.66	0.05	0.96	2	0.23	0.03	0.67	-	-	-	-
Melanopsidium nigrum Colla	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Palicourea fulgens (Müll.Arg.) Standl.	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Posoqueria latifolia (Rudge) Schult.	2	0.26	0.03	0.79	2	0.23	0.05	0.69	1	0.16	0.91	1.31
Psychotria carthagenensis Jacq.	1	0.13	0.01	0.39	2	0.23	0.18	0.83	-	-	-	-
Psychotria mapourioides DC.	5	2.03	0.37	2.03	2	0.23	0.17	0.60	1	0.16	0.01	0.41
Psychotria sp.	1	0.13	0.05	0.44	1	0.11	0.02	0.34	-	-	-	-
Palicourea sessilis (Vell.) C.M.Taylor	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Rubiaceae sp.1	2	0.26	0.67	1.18	-	-	-	-	-	-	-	-
Rubiaceae sp.2	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Rubiaceae sp.3	-	-	-	-	-	-	-	-	1	0.16	0.04	0.44
Rutaceae												
Angostura bracteata (Nees & Mart.) Kallunki	-	-	-	-	1	0.11	0.06	0.38	-	-	-	-
Conchocarpus rubrus (A.St.Hil.) Bruniera & Groppo	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Dictyoloma vandellianum A.Juss.	-	-	-	-	1	0.11	0.20	0.53	-	-	-	-
Pilocarpus sp.	-	-	-	-	-	-	-	-	1	0.16	0.10	0.50
Rauia nodosa (Engl.) Kallunki	1	0.13	0.01	0.39	-	-	-	-	2	0.32	0.61	1.41
Salicaceae												
Casearia arborea (Rich.) Urb.	-	-	-	-	1	0.11	0.08	0.41	-	-	-	-
Casearia cf. ulmifolia Vahl ex Vent.	1	0.13	0.11	0.49	-	-	-	-	-	-	-	-
Casearia commersoniana Cambess.	-	-	-	-	2	0.23	0.09	0.73	-	-	-	-
Casearia javitensis Kunth	-	-	-	-	-	-	-	-	1	0.16	0.02	0.43
Casearia pauciflora Cambess.	-	-	-	-	2	0.23	0.04	0.69	-	-	-	-
Casearia sp.1	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Casearia sp.2	-	-	-	-	-	-	-	-	1	0.16	0.02	0.42
Casearia sp.3	-	-	-	-	-	-	-	-	1	0.16	0.61	1.01
Casearia sylvestris Sw.	-	-	-	-	2	0.23	0.18	0.61	1	0.16	0.03	0.43

Appendix *continue*

Family / Species	ERo				EFo				Int			
	N	RD	RDo	IV	N	RD	RDo	IV	N	RD	RDo	IV
Sapindaceae												
Cupania cf. vernalis Cambess.	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Cupania racemosa (Vell.) Radlk.	14	1.85	1.18	5.02	9	1.02	0.44	2.72	18	2.84	0.69	5.96
Cupania rugosa Radlk.	-	-	-	-	-	-	-	-	2	0.32	0.11	0.91
Cupania sp.	-	-	-	-	1	0.11	0.09	0.41	-	-	-	-
Cupania vernalis Cambess.	1	0.13	0.03	0.41	1	0.11	0.02	0.34	-	-	-	-
Matayba guianensis Aubl.	-	-	-	-	2	0.23	0.05	0.48	2	0.32	0.03	0.83
Matayba sp.	-	-	-	-	-	-	-	-	1	0.16	0.44	0.85
Sapindaceae sp.	1	0.13	0.03	0.41	-	-	-	-	-	-	-	-
Talisia cerasina (Benth.) Radlk.	-	-	-	-	1	0.11	0.02	0.34	1	0.16	0.03	0.43
Talisia sp.	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Sapotaceae												
Chrysophyllum januariense Eichler	2	0.26	0.08	0.84	-	-	-	-	1	0.16	0.09	0.49
Chrysophyllum splendens Spreng.	-	-	-	-	-	-	-	-	1	0.16	0.94	1.34
Diploon cuspidatum (Hoehne) Cronquist	1	0.13	0.01	0.39	-	-	-	-	-	-	-	-
Ecclinusa ramiflora Mart.	5	0.66	0.28	1.69	1	0.11	0.03	0.35	1	0.16	0.29	0.69
Manilkara longifolia (A.DC.) Dubard	-	-	-	-	3	0.34	0.75	1.51	-	-	-	-
Manilkara salzmannii (A.DC.) H.J.Lam	-	-	-	-	1	0.11	0.03	0.35	-	-	-	-
Manilkara subsericea (Mart.) Dubard	-	-	-	-	2	0.23	2.25	2.89	-	-	-	-
Micropholis crassipedicellata (Mart. & Eichler) Pierre	-	-	-	-	1	0.11	0.00	0.33	-	-	-	-
Micropholis gardneriana (A.DC.) Pierre	-	-	-	-	-	-	-	-	3	0.47	0.08	1.03
Micropholis guyanensis (A.DC.) Pierre	1	0.13	0.52	0.89	2	0.23	6.67	7.31	-	-	-	-
Micropholis sp.	-	-	-	-	1	0.11	0.01	0.33	-	-	-	-
Pouteria bangii (Rusby) T.D.Penn.	-	-	-	-	2	0.23	0.03	0.67	-	-	-	-
Pouteria bullata (S.Moore) Baehni	-	-	-	-	3	0.34	0.23	1.19	-	-	-	-
Pouteria caimito (Ruiz & Pav.) Radlk.	3	0.39	0.18	1.08	2	0.23	0.02	0.67	3	0.47	0.13	1.09
Pouteria cf. durlandii (Standl.) Baehni	-	-	-	-	1	0.11	0.09	0.41	1	0.16	0.02	0.42
Pouteria coelomatica Rizzini	4	0.53	0.14	1.17	6	0.68	0.09	1.61	2	0.32	0.07	0.87
Pouteria cuspidata (A.DC.) Baehni	1	0.13	0.04	0.42	1	0.11	0.01	0.33	-	-	-	-
Pouteria guianensis Aubl.	1	0.13	0.03	0.41	-	-	-	-	1	0.16	0.07	0.47
Pouteria microstrigosa T.D.Penn.	-	-	-	-	1	0.11	0.87	1.99	-	-	-	-

Appendix *continue*

Family / Species	ERo				EFo				Int			
	N	RD	RDo	IV	N	RD	RDo	IV	N	RD	RDo	IV
Pouteria pachycalyx T.D.Penn.	-	-	-	-	-	-	-	-	2	0.32	0.35	1.14
Pouteria sp.1	1	0.13	0.18	0.94	-	-	-	-	-	-	-	-
Pouteria sp.2	1	0.13	2.76	3.14	2	0.23	4.51	4.95	-	-	-	-
Pouteria sp.3	-	-	-	-	1	0.11	0.33	0.65	-	-	-	-
Pouteria sp.4	-	-	-	-	-	-	-	-	1	0.16	0.03	0.43
Pouteria sp.5	-	-	-	-	-	-	-	-	1	0.16	0.01	0.42
Pouteria sp.6	-	-	-	-	-	-	-	-	2	0.32	0.11	0.66
Pradosia lactescens (Vell.) Radlk.	1	0.13	0.09	0.48	1	0.11	0.02	0.34	1	0.16	0.01	0.41
Sapotaceae sp.	-	-	-	-	-	-	-	-	1	0.16	0.12	0.52
Schoepfiaceae												
Schoepfia brasiliensis A.DC.	-	-	-	-	5	0.57	0.81	2.22	-	-	-	-
Simaroubaceae												
Simarouba amara Aubl.	2	0.26	0.17	0.93	5	0.57	4.46	5.87	-	-	-	-
Siparunaceae												
Siparuna guianensis Aubl.	4	0.53	0.15	1.42	14	1.59	0.72	3.35	13	2.05	0.87	5.10
Solanaceae												
Solanum sooretamum Carvalho	1	0.13	0.02	0.40	9	1.02	0.19	2.27	14	2.21	0.24	3.89
Symplocaceae												
Symplocos pycnobotrya Mart. ex Miq	-	-	-	-	-	-	-	-	1	0.16	0.45	0.85
Thymelaeaceae												
Daphnopsis cf. fasciculata (Meisn.) Nevling	3	0.39	0.71	1.86	2	0.23	0.03	0.44	1	0.16	0.01	0.41
Urticaceae												
Pourouma guianensis Aubl.	-	-	-	-	1	0.11	0.06	0.38	-	-	-	-
Violaceae												
Rinorea bahiensis (Moric.) Kuntze	1	0.13	0.01	0.38	7	0.79	0.87	2.92	3	0.47	0.05	1.25
Vochysiaceae												
Vochysia cf. angelica M.C.Vianna & Fontella	-	-	-	-	-	-	-	-	1	0.16	0.01	0.41

N = number of individuals, RD = relative density (%), RDo = relative dominance (%) and IV = importance value