Floristic and structural status of forests in permanent preservation areas of Moju river basin, Amazon region

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Received: March 20, 2015 – Accepted: August 10, 2015 – Distributed: November 30, 2016
(With 5 figures)

Abstract

The goal of this study is to analyze the floristic patterns and the structure of disturbed and undisturbed upland forests, in Permanent Preservation Areas (PPAs) along the Moju river, in the Brazilian state of Pará. Trees with a diameter equal to or larger than 10cm at 1.30m from the ground (DBH) ≥10cm were analyzed for the upper stratum. For the middle stratum, individuals with DBH between 4.99 and 9.99cm were sampled. Forty-five families and 221 species were found in disturbed forests, and 43 families and 208 species in undisturbed forests. Floristic similarity was high between strata and between forest types, with values above 50%. Similarity was highest between middle strata. The most species-abundant families in undisturbed forests were Fabaceae, Sapotaceae, Chrysobalanaceae and Myrtaceae; the species with the highest density there were *Eschweilera grandiflora*, *Licania sclerophylla* and *Zygia cauliflora*. In disturbed forests, the dominant families were Fabaceae, Sapotaceae, Lecythidaceae and Melastomataceae. The Shannon-Wiener diversity index was 3.21 for undisturbed forests and 2.85 for disturbed forests. Non-metric multidimensional scaling (MDS) analysis did not group the forests by their floristic composition in both upper and middle strata. Overall, the PPA forests along the Moju river, even if disturbed, did not show major floristic changes but substantially change their structural characteristics.

Keywords: remnant forests, Amazon, forest degradation.

Comparação florística e estrutural de florestas em áreas de preservação permanente do rio Moju, região Amazônica

Resumo

Este estudo teve como objetivo analisar os padrões florísticos e a estrutura de florestas ripárias perturbadas e não perturbadas inseridas em Áreas de Preservação Permanente ao longo do rio Moju, Pará. A análise do estrato superior foi realizada em árvores com diâmetro a 1,30 m do solo (DAP) ≥10 cm. No estrato médio, amostrou-se os indivíduos com DAP entre 4,99 e 9,99 cm DAP. Nas florestas perturbadas foram encontradas 45 famílias e 221 espécies e nas florestas não perturbadas, 43 famílias e 208 espécies. A similaridade florística foi elevada entre os estratos e entre os tipos de florestas, alcançando valores maiores de que 50%. A maior semelhança foi encontrada entre os estratos médios. As famílias mais abundantes em espécies nas florestas não perturbadas foram Fabaceae, Sapotaceae, Chrysobalanaceae e Myrtaceae. As espécies com maiores densidades foram *Eschweilera grandiflora*, *Licania sclerophylla* e *Zygia cauliflora*. Nas florestas perturbadas, as famílias dominantes foram Fabaceae, Sapotaceae, Lecythidaceae e Melastomataceae. A diversidade (Shannon) nas florestas não perturbadas foi de 3,21, e nas florestas perturbadas, alcançaram 2,85. A ordenação feita pelo escalonamento multidimensional MDS, não agrupou as florestas por sua composição florística, tanto no estrato superior como no médio. Em geral, as florestas perturbadas das APPs do rio Moju, mesmo se perturbadas, não evidenciam grandes mudanças florísticas, mas apresentam alterações nas suas características estruturais.

Palavras-chave: florestas remanescentes, Amazônia, degradação florestal.

1. Introduction

Riparian forests in Amazonia are plant formations with a floristic composition and vegetation structure quite similar to those of upland forest areas, and are therefore considered as such. They are located along the edges of water courses and perform an important environmental role, mainly in the prevention of soil erosion and stilting of rivers, maintaining water quality and contributing to the preservation of biodiversity. Brazilian law considers them Areas of Permanent Preservation (PPAs, or APPs in Portuguese) (Brasil, 2002).

The concept of Permanent Preservation Areas in the Forest Law of 1965 emerged to ensure the integrity of the vegetation for maintaining the physical and biological equilibrium in Brazilian biomes. These are areas exclusively for preservation and cannot be utilized for agricultural or farming activities, forest extraction or recreational uses (Sparovek et al., 2011). Despite being protected by law, these forests are widely threatened in Brazil by deforestation and anthropogenic activities. In Moju municipality, Pará state, 29.3% of the PPAs were disturbed by land uses and the application of the new Brazilian Forest Code will result in the loss of ≈60% of forest vegetation from the PPAs in this county (Almeida and Vieira, 2014). The conservation role of PPAs presumably increases in highly deforested regions, such as the Belém Area of Endemism, that has reached at least 75% of the original extent and further extensive forest loss (Almeida and Vieira, 2010; Amaral et al., 2012).

It is therefore of foremost importance to develop studies describing the plant communities of those protected areas in order to provide a picture of the remaining biodiversity and its distribution in the landscape. Lack of studies on floristic composition, structure and conservation status of PPAs, allied to social and environmental problems in Amazonia have hindered the adoption of practices towards the restoration and conservation of those areas of permanent preservation. Within this context, this study aims at analyzing and comparing floristic diversity and structure of forests with different status of conservation in Permanent Preservation Areas in the municipality of Moju, state of Pará, and discuss their importance for the conservation and restoration of those areas.

2. Material and Methods

2.1. Study area

The study was conducted in the municipality of Moju, eastern Pará, Brazil, in Permanent Preservation Areas of rural properties in the Moju river basin (01° 26' 31.7"-02° 24' 31.3"S and 048° 26' 54.2"-048° 59' 21.8"W). Local climate is of the type Ami, according to Köppen's classification (Nascimento and Homma, 1984). Average annual temperatures are high, varying between 25ºC and 27ºC. Annual rainfall is between 2000mm and 3000mm, irregularly distributed, being more concentrated (about 80%) from January to July; however, a short period of drought usually occurs between September and November. Relative air humidity is around 85% (Costa et al., 1998). Predominant soil types are Yellow Latosols of different textures, with Red-Yellow Podzols, Poorly Humic Gleysols and Plinthosols occurring as well (Santos et al., 1985; Costa et al., 1998). The original vegetation of this region of northeastern Pará, where the municipality of Moju is located, included extensive areas of ombrophilous dense forest (Rodrigues et al., 1997). The creation of the PA-150 highway led to intensive human occupation of the region with concomitant timber extraction and agricultural development such that by 2010 only 60% of its original vegetation cover remained, with much of this highly degraded (Almeida and Vieira, 2014). PPAs cover about 5% of the municipality of Moju, and are being subjected to strong pressures due to the expansion of agricultural activities and the cultivation of African oil palm (dendezeiro); some 28% of those PPAs are already in an illegal condition (Almeida and Vieira, 2014).

Location of PPA areas for this study was carried using satellite images followed by fieldwork. Area selection was conducted in the field, according to the following criteria: presence or absence of fire events and logging operations and availability of places authorised by community leaders in the municipality.

The selected areas were covered by upland ombrophilous dense forest (Pires, 1973), with a large number of 25-50m tall trees (Serrão et al., 2003) in unflooded terrain of the riparian zone of Moju river. Two types of forest were identified according to conservation status: disturbed forest and undisturbed forest.

Disturbed forests within PPAs, in illegal condition vis-à-vis the Brazilian Forest Law, were defined as a result of a process of degradation caused by a selective extraction of timber and regular occurrence of fire (Nepstad et al., 1999). Conversely, undisturbed forests within PPAs were defined by the presence of well-established forest strata and absence of visible disturbance, as the occurrence of stumps and fire scars.

2.2. Data collection and analysis

Data was collected in 2011 in plots belonging to small farmers in six rural communities in the municipality of Moju: Vila Olho D'água, Vila Soledade, Vila São Jorge, Vila São Tomé, Vila São Pedro, Vila Braulande (Figure 1). In each rural community, one area of undisturbed forest and one of disturbed forest were selected along the riparian strip of the Moju river.

Two plots of 250m x 10m (5000m^2), located at least 40m away from each other and positioned lengthwise along the river course, were established for each type of forest (disturbed and undisturbed). In total 12 plots per forest type were sampled, totaling 3ha. The upper stratum, with trees of DBH ≥ 10cm, was thoroughly surveyed. For the middle stratum, trees with DBH ≥ 5.0cm and ≤ 9.99cm were inventoried in five subplots of 25m x 10m (1250m^2), randomly distributed within each plot. Palm trees forming a stool were considered as a single individual, of which the DBH of a single stipe was measured. Plant species were identified under field conditions by experienced parabotanists (Nelson Rosa and Carlos Alberto Silva) from the Museu Paraense Emílio Goeldi (MPEG). Voucher samples of specimens which defied confident field identification were collected and taken for comparison with reference material at the MG herbarium. Our taxonomy follow Haston et al. (2009).

To generate aerial biomass estimates (as Mg.ha^{-1}) we used allometric equations for classes with 5cm ≤ DBH < 20cm and DBH ≥ 20cm. Each tree was measured with an ordinary measuring tape in order to obtain CBH

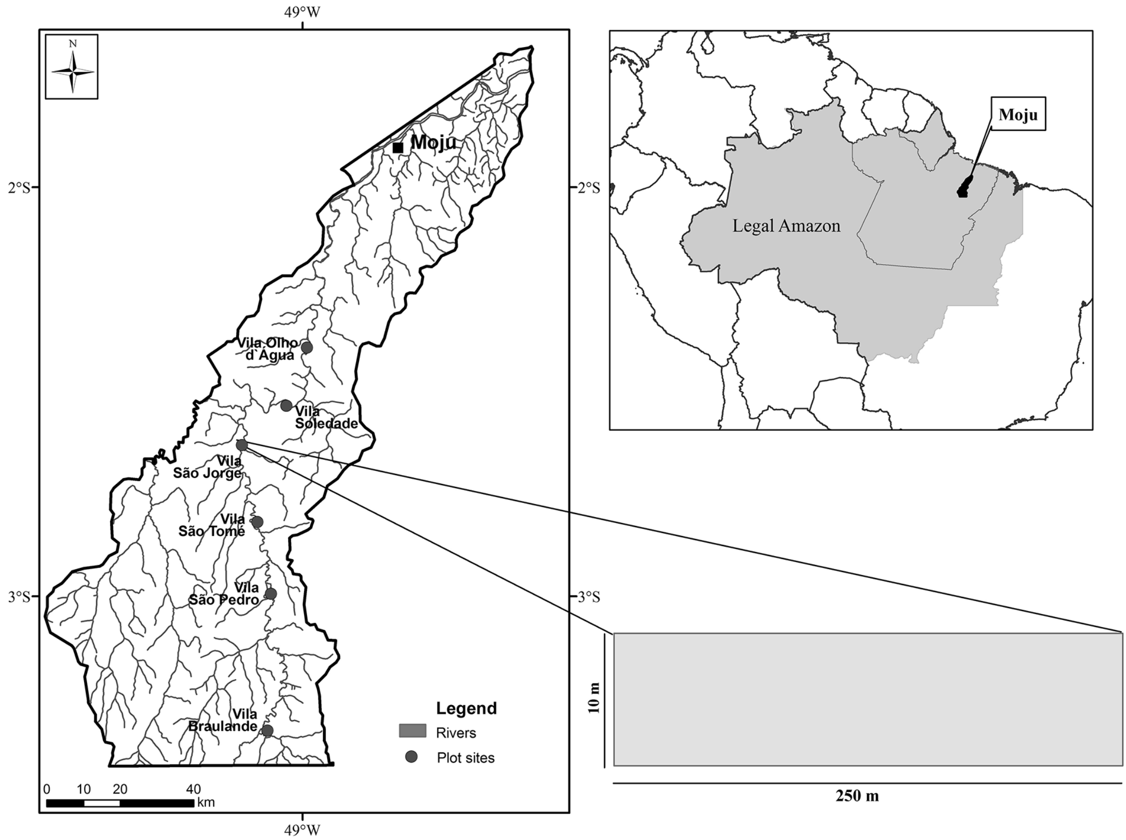

Figure 1. Location of study area, Moju, state of Pará, Amazon region.

values (circumference at 1.30m from the ground), later converted into DBH. Total tree height was estimated in the field using a 5m stick. Allometric equations following Higuchi et al. (1998) were generated by means of a consistent model with the lesser amplitude of standard deviation: P= 0,0336*(D^(2,171))*(H^(1,038)) for 5cm ≤ DBH < 20cm; P= 0,0009*(D^(1,585))*(H^(2,651)) for DBH ≥ 20cm, where: P = weight of fresh mass (kg); D = diameter at 1.30m from the ground (DBH); H = total height. Student t-tests were used to compare diversity and biomass for undisturbed and disturbed forests, at a 5% significance level. Distributions of DBH for each type of forest were tested for similarity with a Kolmogorov–Smirnov two-sample test (Sokal and Rohlf, 1995).

Floristic diversity for the upper and middle forest strata was calculated by Shannon-Wiener Diversity Index (H') and evenness (J') was calculated using Pielou Index (Magurran, 2004).The Sørensen diversity index was used to compare similarity between the strata (Mueller-Dumbois and Ellenber, 1974).The software Mata Nativa (Cientec, 2002) was used for analysis.

A multidimensional scaling analysis (MDS) was performed with the Systat 12.0 program to detect possible dissimilarities between the two forest types, from matrices of abundance of tree species in the upper and middle strata. The Bray-Curtis distance method was adopted for the quantitative data matrix (abundance). A similarity analysis (ANOSIM) was used, using the Bray Curtis distance with 999 permutations, to test the significance of the groups generated in the ordination. The ANOSIM was run in the program PRIMER v 6 (Clarke and Gorley, 2006).

3. Results

Considering all sampled plots and the upper and middle strata of the two types of forests, a total of 4227 individuals belonging to 47 families and 270 species were identified. Undisturbed forests accounted for 2060 individuals of 43 families and 208 species, and disturbed forests for 2167 individuals of 45 families and 221 species.

Families with the largest contribution to floristic richness in undisturbed forests were: Fabaceae, with 51 species (24.52%); Sapotaceae, with 16 species (7.69%); Chrysobalanaceae and Myrtaceae, with 12 species each (5.77%). Families with the highest density were Fabaceae (718), Chrysobalanaceae (272) and Lecythidaceae (251), together making up for 60.24% (1241 individuals) of the total found in this forest type.

In disturbed forests, the most representative families in number of species were Fabaceae, with 50 species (22.62%); Sapotaceae, with 14 species (6.33%); Lecythidaceae and Melastomataceae, with 11 species each (4.98%).

The most abundant families there were also Fabaceae (633), Lecythidaceae (344) and Chrysobalanaceae (283), together representing 58.14% (1260 individuals) of the total found in disturbed forests.

In the upper stratum of undisturbed forests the family Fabaceae stood out in terms of species richness, as well as Lecythidaceae and Chrysobalanaceae, which also fared well in the upper stratum of disturbed forests. Fabaceae showed high values of species richness in any forest type. In the middle stratum, the families Fabaceae, Annonaceae and Melastomataceae made up 31.41% of its number of species. As for the environment where they occur, Fabaceae stood out in more preserved forests and again proved to be indifferent to disturbance.

The most abundant species in undisturbed forests (Table 1; Appendix 1) were *Eschweilera grandiflora* (Aubl.) Sandwith (151 individuals) and *Licania sclerophylla* (Hook. f.) Fritsch (90 individuals), while in disturbed forests they were also well represented (193 and 70 individuals respectively), as were also *Licania heteromorpha* Benth. (131 individuals) and *Euterpe oleraceae* Mart. (87 individuals). Respectively, 17 and 19 species (8.17% and 8.6% of sampled totals) accounted for 50% of all tree individuals with DBH >5cm sampled in undisturbed and disturbed forests.

Species exclusive to undisturbed forests added up to 49 (30 of them rare, that is, with a single individual). Conversely, 62 species were exclusive to disturbed forests, with a higher density of *Cochlospermum orinocense* (Kunth) Steud.

The upper and middle strata of undisturbed forests had higher values for richness and floristic diversity index than those of disturbed forests. However, considering both strata, undisturbed forests exhibited 2060 individuals, 43 families and 208 species, in contrast to, respectively, 2167, 45 and 221 in disturbed forests (Table 2). Comparing forest types, there is higher species richness and significance

Table 1. List of the 30 most abundant species, with density values (ind/ha) recorded in plots in the upper and middle strata in undisturbed and disturbed forests in Permanet Preservation Areas -PPAs within the municipality of Moju, Pará.

Species	Undisturbed Forest		Disturbed Forest	
	Upper strata	Middle strata	Upper strata	Middle strata
Eschweilera grandiflora (Aubl.) Sandwith	40.66	19.33	48.66	31.33
Licania heteromorpha Benth.	13.00	7.33	29.33	28.66
Euterpe oleracea Mart.	7.66	34.66	15.66	26.66
Licania sclerophylla (Hook. f.) Fritsch	17.33	25.33	12.66	21.33
Inga brachyrhachis Harms	8.66	28.66	9.00	24.00
Zygia cauliflora (Willd.) Killip	8.66	39.33	3.66	22.00
Cynometra marginata Benth.	15.66	11.33	12.00	9.33
Hevea brasiliensis (Willd. ex A. Juss.) Müll. Arg.	15.66	0.66	15.33	4.00
Taralea oppositifolia Aubl.	16.33	2.66	11.33	2.00
Caraipa grandifolia Mart.	6.33	28.66	5.00	7.33
Eschweilera coriacea (DC.) S.A. Mori	10.66	6.66	13.66	2.00
Vatairea guianensis Aubl.	12.00	-	12.66	2.66
Eugenia flavescens DC.	-	14.66	6.66	20.00
Swartzia acuminata Willd. exVogel	13.66	2.66	6.66	4.66
Anacardium giganteum W. Hancock ex Engl.	14.00	8.66	4.66	0.66
Swartzia racemosa Benth.	7.33	8.66	5.66	11.33
Licania apetala (E. Mey.) Fritsch	9.33	6.00	8.00	3.33
Gustavia augusta L.	3.33	4.00	11.33	8.66
Licania macrophylla Benth.	12.00	4.66	4.66	2.66
Eschweilera apiculata (Miers) A.C. Sm	7.66	-	10.33	3.33
Tachigalia myrmecophila (Ducke) Ducke	6.66	4.66	5.00	10.66
Macrolobium pendulum Willd. ex Vogel	8.00	2.00	7.33	4.00
Dialium guianense (Aubl.) Sandwith	5.33	5.33	7.00	4.66
Attalea maripa (Aubl.) Mart.	6.33	-	20.66	-
Eugenia omissa Mc Vaugh	2.33	8.66	2.00	12.66
Crudia oblonga Benth.	5.33	1.33	7.00	3.33
Inga splendens Willd.	5.66	3.33	6.00	2.66
Unonopsis guatterioides R.E. Fr.	3.66	9.33	2.33	7.33
Inga capitata Desv.	4.33	4.00	6.00	3.33
Mora paraensis (Ducke) Ducke	10.66	1.33	2.33	-

(t = 2.891 p < 0.05) of the diversity index in well-preserved forests than in the upper stratum of disturbed forests; the same relationship was found in the middle stratum (t = 3.577 p < 0.05). Pielou index is higher in undisturbed forests.

The similarity indices between the upper strata of undisturbed forests and disturbed forests, and between the middle strata of each type, were the highest found (Table 3); no index was lower than 50%, suggesting a certain floristic resemblance between forest types.

Considering both undisturbed and disturbed forests, the mean density of individuals in the upper stratum was 468 ind/ha, and the mean basal area, 25.98m^2/ha. In the middle stratum, the mean density was 470 ind/ha and the mean basal area, 1.90m^2/ha (Table 4).

Distribution of the number of individuals per diameter class tended to follow a negative exponential function (inverted J), with many small-diameter individuals and few large-diameter ones (Figure 2).*Swartzia acuminata* Willd.ex Vogel and *Taralea oppositifolia* Aubl.were the species with the highest number of individuals with diameters above 70cm in undisturbed forests; in disturbed forests, the species with the most numerous large-diameter individuals were *Eschweilera coriacea* (DC.) S.A. Mori and *Bertholletia excelsa* Bonpl. We observed that in the DBH ≤ 10cm class, the number of individuals per hectare was higher in disturbed (494.67) than in undisturbed forests (451.33); also, the 10cm ≤ DBH ≤ 20cm class exhibited the widest difference between the two forest types, with 225 individuals per hectare recorded in undisturbed forests and 298.67 individuals/ha in disturbed forests (Figure 2).

Table 2. Floristic information on tree species in undisturbed and disturbed forests within PPAs in the municipality of Moju, Pará.

Stratum/Floristics	Nº Ind.	H'	J'	Nf	Ng	Ns
Undisturbed forest	2060			43		208
Upper stratum (DBH ≥ 10cm)		3.36	0.91	40	101	167
Middle stratum (9.99cm ≥ DBH ≥ 5.0cm)		3.06	0.92	37	95	134
Disturbedforest	2167			45		221
Upperstratum (DBH ≥ 10cm)		3.05	0.85	39	100	164
Middle stratum (9.99cm≥ DBH ≥ 5.0cm)		2.64	0.84	40	110	156

Nº Ind. = number of individuals, H' = Shannon-Wiener Diversity Index, J' = Pielou Equability Index, Nf = number of families, Ng = number of genera, Ns = number of species.

Table 3. Sørensen Similarity Indices for undisturbed and disturbed riparian forests within PPAs in the municipality of Moju, Pará, considering two strata.

Stratum/Floristic similarity	Undisturbed forest		Disturbed forest	
	US	MS	US	MS
Undisturbed forest - US	-	0.51	0.63	0.56
Undisturbed forest - MS		-	0.54	0.66
Disturbed forest - US			-	0.58
Disturbed forest - MS				-

US, upper stratum; MS, middle stratum.

Table 4. Mean density (number of individuals/ha), aerial biomass (Mg.ha^{-1}) and basal area (m^2/ha) for undisturbed and disturbed forests within PPAs in the municipality of Moju, Pará. (n= 12, 2500 m^2 for each upper stratum plot; n= 12, 1250 m^2 for each middle stratum plot).

Stratum/Structure	Density	Biomass	Basal Area
Undisturbed forest			
Upper stratum	461.00	341.90 ± 83.30	31.02 ± 9.06
Middle stratum	451.33	11.65 ± 2.26	1.89 ± 0.28
Total	912.33	353.35 ± 83.02	32.91 ± 9.08
Disturbed forest			
Upper stratum	475.00	230.50 ± 23.89	20.95 ± 3.78
Middle stratum	494.67	12.48 ± 4.45	1.92 ± 0.47
Total	969.67	242.98 ± 26.19	22.86 ± 3.65

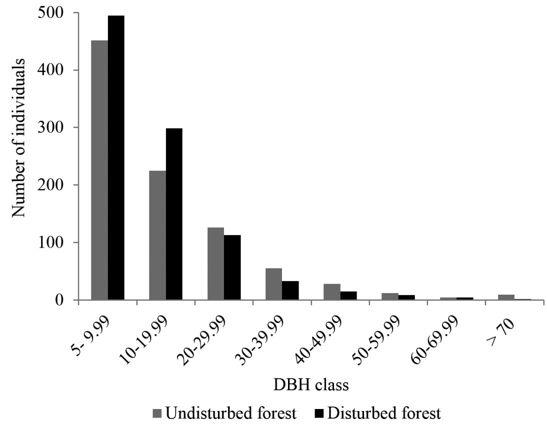

Figure 2. Number of individuals/ha distributed in different DBH classes in disturbed and undisturbed forests within PPAs in the municipality of Moju, Pará.

Those pattern of diameter distribution in both upper and middle strata did not present differences between forest types as showed by Kolmogorov-smirnov test (Ks max = 0.250, p= 0.906).

Aerial biomass was 353.35 Mg.ha^{-1} for undisturbed forests and 242.98 Mg.ha^{-1} for disturbed forests. Vila Braulande had the highest biomass values for both strata (392.20 Mg.ha^{-1}), a major contribution for the high value found in undisturbed forests; this locality also had the highest mean biomass value (257.60 Mg.ha^{-1}). Differences between forest types were statistically significant ($t = 4.263$ $p < 0.05$) (Figure 3; Table 3). The mean basal area of the upper stratum of disturbed forests was smaller (20.95 m^2/ha) than the value found for undisturbed forests (31.02 m^2/ha).

The first and second axes of the NMDS in disturbed and undisturbed forest plots (stress value = 0.15 and 0.21 for upper and middle strata) did not group the forests by their floristic composition (Figure 4). This result was confirmed by ANOSIM analysis (R =0.026, p= 0,27, 999 permutations) which suggest that the disturbance observed in the forest plots is not interfering in species composition of tree communities studied for trees with dbh ≥ 10 cm and for individuals between 5 and 10 cm DBH.

However we observed the formation of two groups in the middle stratum of both disturbed and undisturbed plots (Figure 4b). The first group was formed by the localities of Vila Olho D'água, Vila São Tomé and Vila Braulande; the second by Vila Soledade, Vila São Jorge and Vila São Pedro. The distribution of species richness, abundance and basal area for each forest type of these rural villages were showed in Figure 5.

4. Discussion

The results in the present study revealed that the species richness and abundance of Permanent Preservation Areas forests of Moju river were comparable to other terra firme forests of eastern Amazonia (Salomão et al., 1988; Amaral et al., 2012). The most of the individual stems belong to a relatively small number of species and many of these species are hyperdominants (Ter Steege et al., 2013). Also the floristic richness observed in the upper and middle strata in the PPAs surveyed (208 species in undisturbed forests, 221 in disturbed ones) was considered high in comparison with other PPAs areas studied in the same region (Pinheiro et al., 2007), where 158 were sampled.

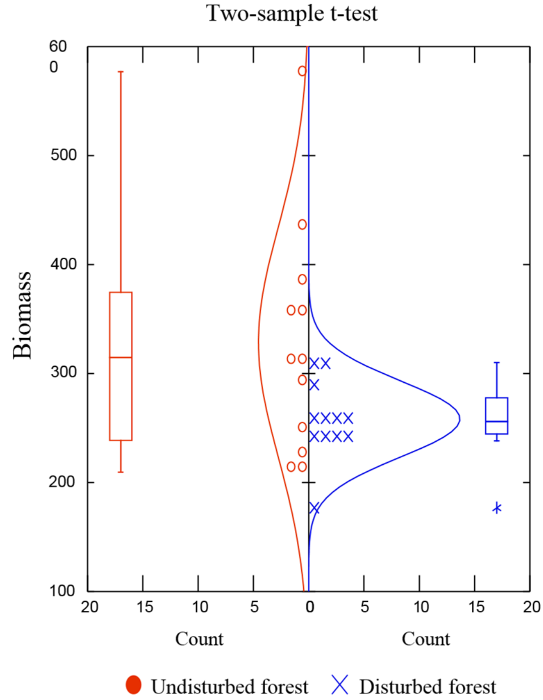

Figure 3. Student's t-test for mean biomass in undisturbed and disturbed forests within PPAs in the municipality of Moju, Pará.

This study found higher species richness in disturbed than undisturbed forests (Table 3). Of the 270 species sampled in the two forest types of Moju, only 96 (36%) were common to both, 62 exclusive to disturbed forests in PPAs and 49 found only in undisturbed forests. The cause of such high richness should be attributed to the higher environmental heterogeneity resulting from disturbances in the uniform structure of the forest. In the case of the forests of Moju, it should be noted that, from the 270 species sampled, only 19 accounted for about 50% of the total number of individuals found: those are hyperdominant species, as defined by Ter Steege et al. (2013). In the forests near Moju, Rodrigues et al. (1997) found about 51% of individuals belonging to only nine species, a situation frequent in throughout the Amazonian forest region.

The family Fabaceae predominate in terms of species richness in both undisturbed and disturbed forests. It is highly frequent in the Neotropics (Ribeiro et al., 1999), and its richness in vegetation formations in Amazonia is mentioned by many authors who verified its wide geographic

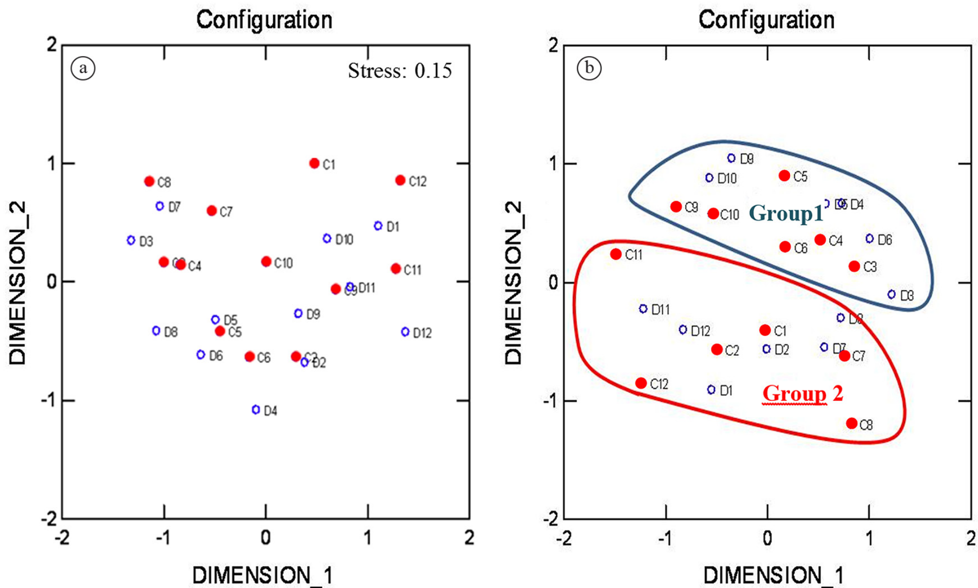

Figure 4. MDS analysis performed for tree species composition in the upper (a) and middle (b) strata for 24 plots of undisturbed and disturbed forests within PPAs, where: C = undisturbed forests; D = disturbed forests; 1 and 2 = Vila Olho D'água; 3 and 4 = Vila Soledade; 5 and 6 = Vila São Jorge; 7 and 8 = Vila São Tomé; 9 and 10 = Vila São Pedro; 11 and 12 = Vila Braulande.

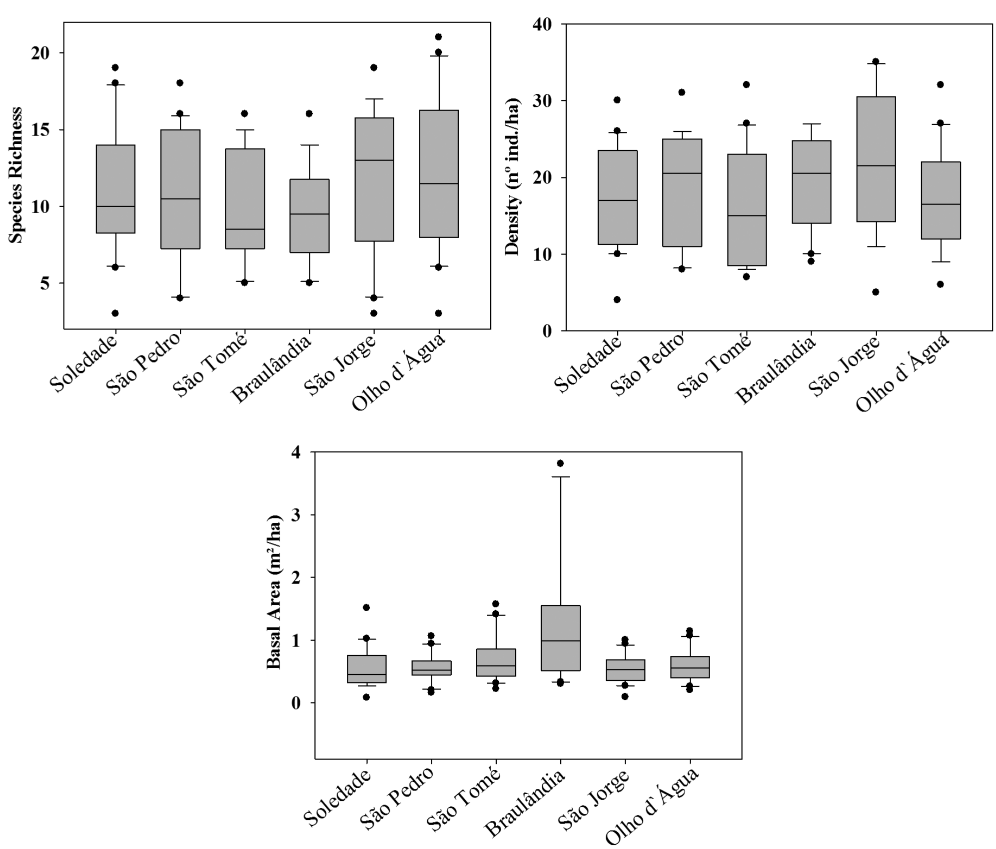

Figure 5. Box-plot showing the distribution of richness, density and basal area of disturbed and undisturbed forests in PPAs of six rural communities studied in Moju, Pará.

distribution and high ecological plasticity (Pires, 1973). In areas dominated by upland forests in Amazonia, the families Sapotaceae, Moraceae and Burseraceae are also referred to as the most species-rich in other floristic inventories in the region (Pires, 1973; Prance et al., 1976; Dantas et al., 1980; Amaral et al., 2012). Other families found in the present study were Chrysobalanaceae and Lecythidaceae, which in Amazonia exhibit the highest densities of individuals and species, along with the Fabaceae (Oliveira and Amaral, 2004).

Overall, the disturbed forests surveyed had lower basal area values (20.95m^2) than those recorded for upland forests in Amazonia, which are of about 30-40 m^2 (Salomão et al., 1988; Pitman et al., 2001). The aboveground biomass was higher in undisturbed forests than in disturbed ones, which had undergone selective logging common practice in the Moju river basin. Vila Braulande had the highest biomass value (392.20 Mg.ha^{-1}), evidencing its high degree of protection in comparison to other undisturbed forests, and especially to those classified as disturbed. That community collects only non-wood forest resources, such as oils and resins, which could have had an effect on this level of protection. In general, the response of the forests to disturbance is different in each rural communities (Figure 5). The mosaic of preserved and degraded forests present in an anthropogenic landscape such as these of Moju is the result of both the rural land use dynamics and the Forest Code, by requiring that 80-50% of the properties must be maintained as legal reserves (reserva legal) does not provide guidance as to its conservation status and format.

This study suggests that the impacts caused by humans on the Moju river communities did not lead to great floristic changes. Also, there were no significant differences between the analysed strata with respect to floristics (richness, Shannon-Wiener diversity, density). However, man-made impacts were perceptible in the tree community structure. As for the floristic composition, multivariate analysis evidenced there are no clear differences between forests respectively considered undisturbed and disturbed, which could be due to the different stages of preservation in PPAs or to their low level of exploitation by local communities – which have not seriously impacted the forest under their domain.

5. Conclusions

Floristic data on richness, abundance and tree species composition did not show any association with the conservation status of the PPAs, indicating that even the disturbed PPAs support viable populations of many tree species, therefore they should be maintained within rural properties. Moreover, the disturbance of forests within the PPAs seems to have been slight, not having significantly jeopardized the community of tree plants with respect to floristics. This favors the use of the most abundant species in the recovery of disturbed PPAs. The impact in the structure of the tree assembly was perceptible in such a way that disturbed forests exhibited a smaller basal area and biomass.

Acknowledgements

This paper forms part of a thesis prepared for the Master's graduate program in Biological Sciences at Museu Paraense Emilio Goeldi in conjunction with the Universidade Federal Rural da Amazônia. We are grateful to the Instituto Nacional de Ciência e Tecnologia, Biodiversidade e Uso da Terra na Amazônia (CNPq grant 574008/2008-0), for financial supportand to CNPq for an MScs cholarship to JCO and a productivity grant (CNPq 306368/2013-7) to ICGV.

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Appendix 1. List of families/species (and their abundance values) recorded in plots in the upper (N= 12, 2500m^2; 3 ha sampled) and middle strata (N= 60, 250m^2; 1.5 ha sampled) in both undisturbed and disturbed forests in Permanent Preservation Areas -PPAs within the municipality of Moju, Pará, Brazil.

Family/Specie	Number of individuals sampled	
	Undisturbed forests	Disturbed forests
ANACARDIACEAE		
Anacardium giganteum W. Hancock ex Engl.	55	15
Spondias mombin L.	-	1
Tapirira guianensis Aubl.	15	15
ANNONACEAE		
Annona densicoma Mart.	2	1
Duguetia echinophora R.E. Fr.	-	4
Duguetia quitarensis Benth.	3	-
Duguetia riparia Huber	1	-
Duguetia sandwithii R.E. Fr.	-	2
Duguetia spixiana Mart.	2	-
Guatteria poeppigiana Mart.	-	3
Guatteria schomburgkiana Mart.	-	5
Unonopsis guatterioides R.E. Fr.	25	18
Xylopia amazonica R.E. Fr.	-	2
Xylopia benthamii R.E. Fr.	-	2
Xylopia cayennensis Maas	-	1
Xylopia nitida Dunal	3	3
APOCYNACEAE		
Ambelania acida Aubl.	4	-
Aspidosperma excelsa Marcondes-Ferreira	-	1
Aspidosperma nítida Woodson	-	1
Himatanthus sucuuba (Spruce ex Müll. Arg.) Woodson	-	2
Malouetia lata Markgr.	-	1
ARALIACEAE		
Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin	5	5
ARECACEAE		
Astrocaryum gynacanthum Mart.	6	-
Astrocaryum jauari Mart.	2	2
Astrocaryum murumuru Mart.	1	1
Astrocaryum vulgare Mart.	-	10
Attalea maripa (Aubl.) Mart.	19	31
Bactris maraja Mart.	1	7
Euterpe oleracea Mart.	75	87
Mauritia flexuosa L. f.		1
Oenocarpus bacaba Mart.	9	4
Syagrus cocoides Mart.	2	3
BIGNONIACEAE		
Jacaranda copaia (Aubl.) D.Don	14	20
BIXACEAE		
Cochlospermum orinocense (Kunth) Steud.	-	11
BORAGINACEAE		
Cordia exaltata Lam.	7	11
Cordia scabrida Mart.	1	-
Cordia tetrandra Aubl.	1	-

Appendix 1. Continued...

Family/Specie	Number of individuals sampled	
	Undisturbed forests	Disturbed forests
BURSERACEAE		
Protium apiculatum Swart	-	3
Protium heptaphyllum (Aubl.) Marchand	20	10
Protium krukoffii Swart	1	-
Protium pilosum (Cuatrec.) D.C. Daly	-	2
Protium trifoliolatum Engl.	1	3
Tetragastris altissima (Aubl.) Swart	4	-
Trattinnickia burserifolia Mart.		2
Trattinnickia rhoifolia Willd.	1	1
CALOPHYLLACEAE		
Calophyllum brasiliense Cambess.	1	1
Caraipa grandifolia Mart.	62	26
Caraipa richardiana Cambess.	3	6
CELASTRACEAE		
Maytenus myrsinoides Reissek	6	4
CHRYSOBALANACEAE		
Hirtella eriandra Benth.	26	5
Licania apetala (E. Mey.) Fritsch	37	29
Licania canescens Benoist	1	1
Licania guianensis Klotzsch	2	-
Licania heteromorpha Benth.	50	131
Licania licaniiflora (Sagot) S.F. Blake	3	3
Licania macrophylla Benth.	43	18
Licania membranacea Sagot ex Laness.	16	25
Licania oblongifolia Standl.	1	-
Licania parviflora Benth.	2	-
Licania sclerophylla (Hook. f.) Fritsch	90	70
Parinari montana Aubl.	1	1
CLUSIACEAE		
Rheedia brasiliensis (Mart.) Planch. & Triana	15	2
Rheedia macrophylla (Mart.) Planch. & Triana	10	14
Tovomita brasiliensis (Mart.) Walp.	1	1
Tovomita brevistaminea Engl.	1	-
COMBRETACEAE		
Buchenavia ochroprumna Eichler	3	1
Buchenavia oxycarpa (Mart.) Eichler		1
Terminalia argentea Mart.	1	-
Terminalia dichotoma G. Mey.	2	2
EBENACEAE		
Diospyros artanthifolia Mart.	14	19
Diospyros guianensis (Aubl.) Gürke	2	-
ELAEOCARPACEAE		
Sloanea guianensis (Aubl.) Benth.	3	-
EUPHORBIACEAE		
Conceveiba guianensis Aubl.	2	1
Hevea brasiliensis (Willd. ex A. Juss.) Müll. Arg.	48	52
Mabea caudata Pax & K. Hoffm.	10	6
Pogonophora schomburgkiana Miers ex Benth.	1	1
Sagotia racemosa Baill.	-	2

Appendix 1. Continued...

Family/Specie	Number of individuals sampled	
	Undisturbed forests	Disturbed forests
FABACEAE		
Abarema jupunba (Willd.) Britton & Killip	5	5
Acosmium nitens (Vogel) Yakovlev	6	4
Alexa grandiflora Ducke	1	-
Campsiandra laurifolia Benth.	2	27
Crudia oblonga Benth.	18	26
Cynometra marginata Benth.	64	50
Dialium guianense (Aubl.) Sandwith	24	28
Diplotropis martiusii Benth.	-	1
Diplotropis purpurea (Rich.) Amshoff	1	-
Dipteryx odorata (Aubl.) Willd.		2
Eperua bijuga Mart. ex Benth.	15	10
Hydrochorea corymbosa (Rich.) Barneby & J.W. Grimes	17	9
Hymenaea oblongifolia Huber	9	13
Hymenaea parvifolia Huber	1	-
Hymenaea reticulata Ducke	2	1
Inga alba (Sw) Willd.	3	4
Inga brachyrhachis Harms	69	63
Inga capitata Desv.	19	23
Inga disticha Benth.	2	3
Inga edulis Mart.	5	6
Inga grandiflora Wall.	1	5
Inga laurina (Sw.) Willd.	8	12
Inga macrophylla Humb. & Bonpl. ex Willd.	1	3
Inga marginata Willd.	12	9
Inga paraensis Ducke	1	6
Inga splendens Willd.	22	22
Inga thibaudiana DC.	4	5
Inga umbellifera (Vahl) Steud.	-	1
Macrolobium acaciifolium (Benth.) Benth.	1	5
Macrolobium angustifolium (Benth.) R.S. Cowan	8	1
Macrolobium pendulum Willd. ex Vogel	27	28
Mora paraensis (Ducke) Ducke	34	7
Ormosia coutinhoi Ducke	2	4
Parkia discolor Spruce ex Benth.	4	1
Parkia nitida Miq.	2	4
Peltogyne venosa (Vahl) Benth.	2	1
Pentaclethra macrophylla Benth.	11	2
Poecilanthe effusa (Huber) Ducke	1	-
Platymiscium filipes Benth.	-	2
Pseudopiptadenia suaveolens (Miq.) J.W. Grimes	3	1
Pterocarpus officinalis Jacq.	1	2
Stryphnodendron guianense (Aubl.) Benth.	1	1
Stryphnodendron paniculatum Poepp.	-	1
Stryphnodendron pulcherrimum (Willd.) Hochr.	1	3
Swartzia acuminata Willd. ex Vogel	45	27
Swartzia arborescens (Aubl.) Pittier	1	1
Swartzia laurifolia Benth.	-	1
Swartzia racemosa Benth.	35	34

Appendix 1. Continued...

Family/Specie	Number of individuals sampled	
	Undisturbed forests	Disturbed forests
Tachigali goeldiana (Huber) L.F. Gomes da Silva & H.C. Lima	2	-
Tachigalia myrmecophila (Ducke) Ducke	27	31
Tachigalia paniculata Aubl.	1	-
Taralea oppositifolia Aubl.	53	37
Vatairea guianensis Aubl.	36	42
Vouacapoua americana Aubl.	22	11
Zygia ampla (Spruce ex Benth.) Pittier	-	4
Zygia cataractae (Kunth) L. Rico	1	-
Zygia cauliflora (Willd.) Killip	85	44
GOUPIACEAE		
Goupia glabra Aubl.	2	4
HUMIRIACEAE		
Sacoglottis guianensis Benth.	-	1
HYPERICACEAE		
Vismia cayennensis (Jacq.) Pers.	1	3
Vismia guianensis (Aubl.) Pers.	-	6
LAURACEAE		
Aniba guianensis Aubl.	7	8
Licaria rigida (Kosterm.) Kosterm.	-	2
Ocotea caudata (Nees) Mez	2	3
Ocotea glomerata (Nees) Mez	1	1
Ocotea longifolia Kunth	-	1
Ocotea rubra Mez	-	1
LECYTHIDACEAE		
Allantoma lineata (Mart.& O.Berg) Miers	7	8
Bertholletia excelsa Bonpl.	-	4
Couratari guianensis Aubl.	1	2
Eschweilera amazonica R. Knuth	-	2
Eschweilera apiculata (Miers) A.C. Sm.	23	36
Eschweilera coriacea (DC.) S.A. Mori	42	44
Eschweilera grandiflora (Aubl.) Sandwith	151	193
Eschweilera pedicellata (Rich.) S.A. Mori	7	4
Gustavia augusta L.	16	47
Lecythis idatimon Aubl.	1	1
Lecythis lurida (Miers) S.A. Mori	1	-
Lecythis pisonis Cambess.	2	3
LINACEAE		
Roucheria punctata (Ducke) Ducke	4	1
MALPIGHIACEAE		
Byrsonima densa (Poir.) DC.	1	-
MALVACEAE		
Apeiba burchellii Sprague	3	1
Apeiba echinata Gaertn.	4	-
Eriotheca globosa (Aubl.) A. Robyns	1	2
Eriotheca longipedicellata (Ducke) A. Robyns	1	2
Pseudobombax munguba (Mart. & Zucc.) Dugand	4	-
Sterculia pruriens (Aubl.) K.Schum.	11	3
Sterculia speciosa K. Schum.	-	1
Theobroma speciosum Willd. ex Spreng.	-	4
Theobroma subincanum Mart.	2	1

Appendix 1. Continued...

Family/Specie	Number of individuals sampled	
	Undisturbed forests	Disturbed forests
MELASTOMATACEAE		
Bellucia grossularioides (L.) Triana	1	1
Henriettea succosa (Aubl.) DC.	1	1
Miconia affinis DC.	1	11
Miconia gratissima Benth. ex Triana	-	2
Miconia pyrifolia Naudin	-	2
Miconia tomentosa (Rich.) D. Don ex DC.	1	7
Mouriri acutiflora Naudin	13	1
Mouriri apiranga Spruce ex Triana	5	3
Mouriri brachyanthera Ducke	4	12
Mouriri grandiflora DC.	4	-
Mouriri nervosa Pilg.	-	1
Mouriri nigra (DC.) Morley	3	3
MELIACEAE		
Carapa grandiflora Sprague	1	-
Carapa guianensis Aubl.	19	19
Cedrela odorata Vell.	-	2
Guarea guidonia (L.) Sleumer	2	6
Trichilia micrantha Benth.	11	24
Trichilia quadrijuga Kunth	2	6
MORACEAE		
Brosimum acutifolium Huber	1	-
Brosimum guianense (Aubl.) Huber	23	17
Brosimum parinarioides Ducke	1	-
Brosimum rubescens Taub.	1	-
Clarisia ilicifolia (Spreng.) Lanj. & Rossberg	1	-
Ficus maxima Mill.	-	1
Ficus pertusa L. f.	-	1
Helicostylis tomentosa (Poepp. & Endl.) Rusby	1	2
Maquira calophylla (Poepp. & Endl.) C.C. Berg	-	1
Maquira guianensis Aubl.	5	4
Perebea mollis (Poepp. & Endl.) Huber	1	-
Pseudolmedia murure Standl.	1	3
MYRISTICACEAE		
Iryanthera laevis Markgr.	-	1
Virola surinamensis (Rol. ex Rottb.) Warb.	8	10
MYRTACEAE		
Eugenia anastomosans DC.	2	2
Eugenia brachypoda DC.	1	-
Eugenia cupulata Amshoff	-	1
Eugenia deflexa Poir.	2	-
Eugenia egensis DC.	1	-
Eugenia feijoi O. Berg	1	1
Eugenia flavescens DC.	22	50
Eugenia lambertiana DC.	4	1
Eugenia omissa Mc Vaugh	20	25
Eugenia patrisii Vahl	2	9
Myrcia eximia DC.	2	-
Myrcia guianensis (Aubl.) DC.	1	4
Myrciaria floribunda (H. West ex Willd.) O. Berg	1	4

Appendix 1. Continued...

Family/Specie	Number of individuals sampled	
	Undisturbed forests	Disturbed forests
NYCTAGINACEAE		
Guapira opposita (Vell.) Reitz	-	1
OCHNACEAE		
Lacunaria crenata (Tul.) A.C. Sm.	1	-
Ouratea paraensis Huber	-	1
OLACACEAE		
Cathedra acuminata (Benth.) Miers	12	11
Chaunochiton kappleri (Sagot ex Engl.) Ducke	2	-
Dulacia candida (Poepp.) Kuntze	2	-
Heisteria acuminata (Bonpl.) Engl.	-	1
Minquartia guianensis Aubl.	5	-
OPILIACEAE		
Agonandra brasiliensis Miers ex Benth. & Hook. f.	-	1
POLYGONACEAE		
Coccoloba latifolia Lam.	8	6
RUBIACEAE		
Alibertia edulis (Rich.) A. Rich. ex DC.	2	1
Botryarrhena pendula Ducke	1	4
Genipa americana L.	-	2
Isertia hypoleuca Benth.	-	1
Posoqueria latifolia (Rudge) Roem & Schoolt	3	19
Posoqueria longiflora Aubl.	1	1
RUTACEAE		
Galipea trifoliata Aubl.	1	8
SALICACEAE		
Casearia decandra Jacq.	-	1
Casearia grandiflora Cambess.	-	1
Casearia pitumba Sleumer	1	1
Casearia ulmifolia Vahl ex Vent.	1	-
SAPINDACEAE		
Cupania scrobiculata Rich.	1	-
Talisia veraluciana Guarim	1	1
Toulicia guianensis Aubl.	2	7
SAPOTACEAE		
Chrysophyllum cuneifolium (Rudge) A. DC.	3	-
Chrysophyllum sparsiflorum Klotzsch ex Miq.	-	3
Ecclinusa abbreviata Ducke	1	-
Manilkara huberi (Ducke) A. Chev.	1	3
Micropholis acutangula (Ducke) Eyma	3	2
Micropholis guyanensis (A. DC.) Pierre	6	1
Micropholis venulosa (Mart. & Eichler) Pierre	5	9
Pouteria caimito (Ruiz & Pav.) Radlk.	1	2
Pouteria decorticans T.D. Penn.	1	2
Pouteria glomerata (Miq.) Radlk.	1	-
Pouteria gongrijpii Eyma	1	10
Pouteria guianensis Aubl.	11	13
Pouteria macrophylla (Lam.) Eyma	1	1
Pouteria robusta (Mart. & Eichler) Eyma	1	3
Pouteria venosa (Mart.) Baehni	2	1

Appendix 1. Continued...

Family/Specie	Number of individuals sampled	
	Undisturbed forests	Disturbed forests
Pradosia granulosa Pires & T.D. Penn.	13	5
Sarcaulus brasiliensis (A. DC.) Eyma	2	6
SIMAROUBACEAE		
Simaba cedron Planch.	-	4
Simaba polyphylla (Cavalcante) W.W. Thomas	-	1
Simarouba amara Aubl.	9	8
SIPARUNACEAE		
Siparuna guianensis Aubl.	2	2
ULMACEAE		
Ampelocera edentula Kuhlm.	12	16
URTICACEAE		
Cecropia distachya Huber	1	-
Cecropia obtusa Trécul	-	2
Cecropia sciadophylla Mart.	-	1
Pourouma guianensis Aubl.	1	-
Pourouma mollis Trécul	-	1
VIOLACEAE		
Amphirrhox surinamensis Eichler	4	1
Rinorea guianensis Aubl.	-	2
Rinorea passoura Kuntze	6	3
Rinorea riana Aubl.	4	5
VOCHYSIACEAE		
Qualea acuminata Spruce ex Warm.	-	2
Ruizterania albiflora (Warm.) Marc.-Berti	-	3
Vochysia vismiifolia Spruce ex Warm.	4	14