# The status of conservation of urban forests in eastern Amazonia

*Amaral, DD., Vieira, ICG.*, Salomão, RP., Almeida, SS.⁺ and Jardim, MAG.*

Coordenação de Botânica, Museu Paraense Emílio Goeldi,
Av. Magalhães Barata, 376, CP 399, CEP 66040-170, Belém, PA, Brazil
⁺In memorian
*e-mail: ima@museu-goeldi.br

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(With 1 figure)

## Abstract

This study aims to identify the remnant tree flora in six forest fragments in the metropolitan area of Belém and to analyze these fragments in terms of biological conservation, species richness and diversity in the local urban landscape. The fragments and their respective sampling areas were as follows: Amafrutas reserve (15 ha), Trambioca Is. reserve (2 ha), Bosque Rodrigues Alves city park (15 ha), Combu Is. reserve (10 ha), Gunma Park reserve (10 ha) and Mocambo reserve (5 ha). Inventories were built from lineal plots of 250 $m^2$ and included trees with DBH equal to or greater than 10 cm at a height of 1.3 m above ground. Sixty-nine families and 759 species, of which eight were officially listed as endangered (Brazilian National Flora: Ministry of Environment, Normative Instruction of September, 2008; Pará State Flora: Decree Nº. 802 of February 2008) were recorded. These endangered species are: *Aspidosperma desmanthum* Benth. ex Müll. Arg. (Apocynaceae), *Cedrela odorata* L. (Meliaceae), *Eschweilera piresii* S.A Mori (Lecythidaceae), *Euxylophora paraensis* Huber (Rutaceae), *Hymenolobium excelsum* Ducke (Leguminosae), *Manilkara huberi* (Ducke) Chevalier (Sapotaceae), *Tabebuia impetiginosa* (Mart. ex DC.) Standl. (Bignoniaceae), *Mezilaurus itauba* (Meisn.) Taub. ex Mez (Lauraceae) and *Qualea coerulea* Aubl. (Vochysiaceae). Emergency actions such as implementing management plans for already existing Conservation Units, the creation of new such units in areas of primary forest fragments (as in the case of the Amafrutas reserve), as well as the intensification of actions of surveillance and monitoring, should be undertaken by Federal, State, and Municipal environmental agencies so as to ensure the conservation of these last primary forest remnants in the metropolitan area of Belém.

*Keywords:* forest remnants, Belém, State of Pará, forest fragmentation.

## Status de conservação das florestas urbanas da Amazônia oriental

## Resumo

O presente estudo teve o objetivo de identificar a flora arbórea remanescente em seis fragmentos florestais da região metropolitana de Belém-PA, além de analisar esses fragmentos em termos de conservação, riqueza e diversidade no cenário urbano da região. Os fragmentos, com respectivas áreas amostradas, foram: Amafrutas (15 ha), Ilha Trambioca (2 ha), Bosque Rodrigues Alves (15 ha), Ilha do Combu (10 ha), Gunma (10 ha) e Mocambo (5 ha). Os inventários foram realizados utilizando-se parcelas lineares de 250 $m^2$, com inclusão de árvores com diâmetro a 1,3 m do solo (DAP) igual ou acima de 10 cm. Foram registradas 69 famílias e 759 espécies, sendo que oito destas estão em listas oficiais de espécies ameaçadas de extinção (Flora Nacional: Instrução Normativa do MMA de setembro de 2008; Flora do Pará: Decreto 802, de fevereiro de 2008). As espécies ameaçadas são: *Aspidosperma desmanthum* Benth. ex Müll. Arg. (Apocynaceae), *Cedrela odorata* L. (Meliaceae), *Eschweilera piresii* S.A Mori (Lecythidaceae), *Euxylophora paraensis* Huber (Rutaceae), *Hymenolobium excelsum* Ducke (Leguminosae), *Manilkara huberi* (Ducke) Chevalier (Sapotaceae), *Tabebuia impetiginosa* (Mart. ex DC.) Standl. (Bignoniaceae), *Mezilaurus itauba* (Meisn.) Taub. ex Mez (Lauraceae) e *Qualea coerulea* Aubl. (Vochysiaceae). Ações emergenciais, como a implementação dos planos de manejo das Unidades de Conservação (UCs) já existentes, a criação de novas UCs em áreas de fragmentos de florestas primárias (como é o caso da área da Amafrutas), bem como o fortalecimento dos serviços de vigilância e fiscalização, devem ser tomadas pelos órgãos ambientais (municipal, estadual e federal), de forma a assegurar a conservação desses últimos remanescentes de florestas primárias da região metropolitana de Belém-PA.

*Palavras-chave:* remanescentes florestais, Belém, Estado do Pará, fragmentação florestal.

## 1. Introduction

The metropolitan area of Belém (including, in addition to the State capital city, the continuous municipalities of Ananindeua, Marituba, Santa Bárbara and Benevides) harbors a population of over 2 million people, and is the most populous metropolitan area in Amazonia (IBGE, 2008). Similarly to the situation in most Brazilian capital cities, it endures a chaotic urban growth, which produces continuous impacts and the elimination of the last remnants of primary forests around the city. Such urban forests are defined as the total sum of all wood vegetation surrounding and involving urban clusters from small rural communities to large metropolitan areas (Miller, 1997).

The region is located within the "Belém Center of Endemism" between the States of Pará and Maranhão (Silva et al., 2005), and represents the oldest and also the most deforested area of human occupation in Brazilian Amazonia. Only 23% of its vegetative cover is intact, and most of the endangered species mentioned in the Pará State Red List occur in this region (Vieira et al. 2007; Almeida and Vieira, 2010).

The original forest cover has been continuously reduced due to the urban expansion of Belém. According to Leão et al. (2007), 597.5 km$^2$ of forests in the metropolitan area of Belém, representing 50% of the total area, were deforested until 1986. In the following twenty years, the region lost 211.2 km$^2$ of its forest cover. All this deforestation corresponds to a yearly average of 21.13 km$^2$. Today, some 369 km$^2$ (31%) of forest remnants are still found in the metropolitan area of Belém (Leão et al., 2007).

Furthermore, according to the same authors, in the continental part of Belém, where 97% of the population is concentrated, green areas in 2006 corresponded to 84.6 m$^2$ per inhabitant. In 2001, there were 96.5 m$^2$ per inhabitant. Thus, a reduction of 11.9 m$^2$ in five years was perceived. The aforementioned study notes that the green areas in Belém are located on the islands and restricted continental spots - plots belonging to the military, or to public education and research institutions such as the Brazilian Agricultural Research Corporation (EMBRAPA), Emílio Goeldi Museum in the State of Pará (MPEG), the Federal University of Pará (UFPa) or the Federal Rural University of Amazonia (UFRA) – and in Conservation Units. Pires and Salomão (2007) believe that it is currently easier to find primary upland forests in the neighborhood of the city São Paulo (Serra da Cantareira) than in the surroundings of Belém (in the heart of Amazonia) where, according to them, such forests are apart from each other by a radius of over 170 km.

Considering these facts, two questions lead the way of the present study: a) What primary flora remains in the metropolitan area of Belém? b) Where are the forest fragments harboring such flora, and what do they represent in terms of conservation, richness and diversity? Within this context, the primary arboreal flora remnants in six important forest fragments in that area were inventoried, and a number of ecological parameters for conservation, richness and diversity were analyzed for those fragments vis-à-vis the local urban landscape. This article complements the checklist of the flora of forest remains in the metropolitan area of Belém by Amaral et al. (2009), and focuses instead on the conservation of these forests.

## 2. Material and Methods

### *2.1. Location of study areas*

Fragments studied are the following: Trambioca Island - Reserve in Barcarena, Mocambo reserve - Area for Ecological Research in Guamá, Gunma Ecological Park, Combu Island - Environmental Protection Area, Bosque Rodrigues Alves city park (now Botanical Garden of Amazonia) and Amafrutas Forest Reserve (Figure 1).

Total sampled area was of 57 ha. Size of the forest fragments varied from 2 ha (Trambioca Is.) to 15 ha (Amafrutas and Bosque Rodrigues Alves). Although less sampled, Trambioca Is. was the second largest area (7,500 ha), together with the Amafrutas fragment (8,000 ha). In turn, Bosque Rodrigues Alves was the smallest fragment (15 ha) (Table 1).

In half of the fragments (Amafrutas, Trambioca, Gunma), two types of vegetation were inventoried: Upland Forests (*Florestas de Terra Firme*) and Floodplain Forests (*Florestas de Várzea*). In the Bosque Rodrigues Alves and the Combu Is., however, research was conducted in upland forests and floodplain forests, respectively. Upland Forests and Wetlands (*Igapós*) were inventoried in the Mocambo reserve. The fragment located nearest to the geographical center of Belém is Bosque Rodrigues Alves, while the farthest one is Gunma Ecological Park – some 35 km on a straight line (Table 1).

All fragments are located within the metropolitan area of Belém (which includes, besides the capital city, the Municipalities of Ananindeua, Marituba, Santa Bárbara and Benevides), with the exception of Trambioca Is. (Municipality of Barcarena). The latter was included in the analysis due to the availability of local data, its proximity to the city of Belém – it is 20 km from the capital, a distance shorter than that between Belém and either Gunma (35 km) or Amafrutas (22 km), besides being an island area such as the Combu Is. fragment, contrary to the other, continental areas.

### *2.2. Vegetation sampling and data analysis*

Floristic data derive from botanical inventories (using lineal plots of 250 m$^2$, or 25 × 10 m) compiled for their respective fragments, where all trees with DBH ≥ 10 cm were included. Sampling intensity in the inventoried areas varied from 2 ha (Trambioca Is.) to 15 ha (Gunma) and does not meet any criterion related to fragment size or sample area. The floodplain plots were arranged parallel to the main drain, considered the low plain (*varzea baixa*).

All inventories were carried out by researchers of the Emílio Goeldi Museum (MPEG), except for the Bosque Rodrigues Alves fragment, where it was conducted by its own Coordination of Flora. All botanical material was

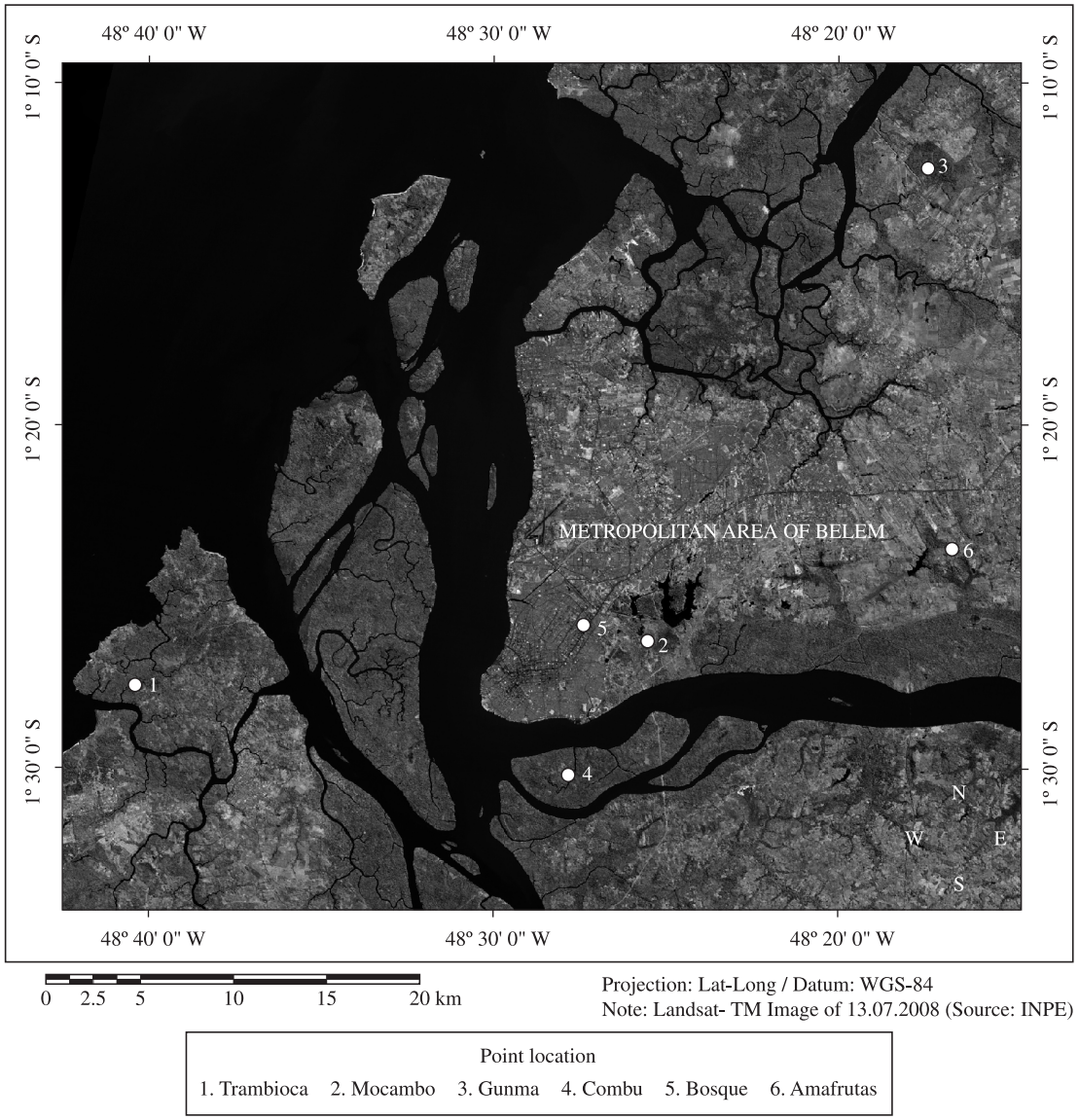


**Figure 1.** Location of fragments of primary forests studied in the metropolitan area of Belem, Pará state: Bosque, Trambioca, Mocambo, Amafrutas, Gunma and Combu Is. (Source: INPE).

collected and brought in for identification to the MPEG Herbarium (MG) (Amaral et al., 2009). Nineteen percent of the trees surveyed were not considered because of identification problems.

Only complete identifications, with full genus names and specific epithets, were taken into consideration. Species were classified according to their ecological group, whether they were pioneer, early secondary, late secondary or climatic species (sensu Budowski, 1965).

The areas were characterized according to the following parameters: legal denomination of fragment (public area, private area, Conservation Unit), municipality to which it pertains, distance on a straight line from the geographic center of Belém (defined as the facilities of the Zoobotanical Park of the Goeldi Museum - 1° 27' 11" S and 48° 28' 35" W), size of inventoried area (in hectares), total size of fragment (in hectares) and types of vegetation present therein.

For each fragment data, the following was obtained: richness (number of species), Shannon-Wiener (base 10) diversity index (H') cf. Magurran (1988), rare species (a single individual of the species/fragment sampled), exclusive species (occurrence restricted to a single fragment) and threatened species (Brasil, 2008; Pará, 2008)

Analyses were conducted on the conservation status of the fragments, considering the size of forest fragments, the access control and surveillance, the connectivity with other fragments, the exploitation of natural resources and the type of neighborhood (urbanization of the surroundings).

According to these parameters, three scenarios of conservation were established for the remnant primary forests in the metropolitan area of Belém. The scale factors of sustainability score were: 0-10 (unfavorable), 11-15 (favorable with restriction), 16-25 (favorable) vis-à-vis those parameters (adapted from Viana and Pinheiro, 1998).

## 3. Results

### *3.1. Richness and diversity*

A total of 31,782 inventoried trees were recorded in the six fragments, pertaining to 759 species in 69 botanical families (Amaral et al., 2009). 19% of inventoried species were not included due to problems of botanical identification. Information on richness, diversity, specific rarity and occurrence in the fragments studied is shown in Table 2. Diversity index H´ varied between 2.58 (Combu) and 4.74 (Gunma).

More than half (52%) of the remnant flora occurs in isolation in one of the fragments and the largest concentration is in Gunma (28.7%; n = 759) and the smallest one in Amafrutas (23.0%; n = 759). Only 5% (n = 759) of the catalogued species were similar among the six areas. Almost half of them (47%; n = 759) are upland forest species, while 36% (n = 759) are floodplain and wetland species; 17% (n = 759) are common to all vegetation types. Some species occur preferentially in the upland forests, for example: *Apuleia leiocarpa* (Vogel) J.F. Macbr., *Alexa grandiflora* Ducke, *Bowdichia nitida* Spruce ex Benth., *Hymenolobium pulcherrimum* Ducke, and many

**Table 1.** Location and information about urban forest remnants inventoried in the metropolitan area of Belém, State of Pará, Brazil.

| Forest fragments | Legal denomination | Coordinates | Distance from Belém (km on a straight line) | Municipality | Size of inventoried area (ha) | Approximate total size of forest fragment (ha) | Types of inventoried vegetation/size of inventoried area (ha) |
|---|---|---|---|---|---|---|---|
| Bosque | Public area (Municipal) | 1° 25' 50" S and 48° 27' 23" W | 3.5 | Belém | 15 | 15 | Upland forest (15) |
| Mocambo | Environmental protection area (Federal) | 1° 26' 20" S and 48° 25' 18" W | 5 | Belém | 3 | 2.200 | Upland forest (2)/ floodplain/wetland (1) |
| Combu | Environmental protection area (State) | 1° 29' 40" S and 48° 27' 46" W | 7 | Belém | 10 | 1.500 | Floodplain forest (10) |
| Trambioca | Public area (Municipal) | 1° 27' 20" S and 48° 40' 25" W | 20 | Barcarena | 2 | 7.500 | Upland forest (1)/ floodplain forest (1) |
| Amafrutas | Private area | 1° 23' 18" S and 48° 17' 22" W | 22 | Benevides | 15 | 8.000 | Upland forest (5)/ floodplain forest (10) |
| Gunma | Private area | 1° 12' 14" S and 48° 17' 39" W | 35 | Santa Bárbara | 10 | 400 | Upland forest (8)/ floodplain forest (2) |
| Total | | | | | 57 | 19.615 | |

**Table 2.** Data on floristics and structure of arboreal species in six primary forests remnants in the metropolitan area of Belém, State of Pará, Brazil.

| Forest fragments | Number of species | Diversity index (H´) | Species with rare populations (one single tree) | | Species exclusive to a single fragment | |
|---|---|---|---|---|---|---|
| | | | Absolute number | % | Absolute number | % |
| Bosque | 258 | 4.45 | 21 | 26.24 | 66 | 25.09 |
| Mocambo | 234 | 4.24 | 38 | 41.77 | 57 | 24.05 |
| Combu | 70 | 2.58 | 0 | 0 | 25 | 35.21 |
| Trambioca | 250 | 4.56 | 56 | 59.60 | 68 | 27.20 |
| Amafrutas | 325 | 4.62 | 21 | 16.67 | 76 | 23.03 |
| Gunma | 379 | 4.74 | 30 | 20.00 | 109 | 28.68 |
| Total | 759 | | 165 | 21.35% | 400 | 51.75% |

others. The following are found in both floodplain and wetland forests: *Hevea camargoana* Pires, *Ormosia excelsa* Benth, *Swartzia acuminata* Willd. ex Vogel and *Vantanea macrocarpa* Ducke. There are still those who co-inhabit the upland forest and alluvial forests (lowland and igapó), examples of which are: *Protium poeppigianum* Swart., *Licania incana* Aubl., *Swartzia macrocarpa* Spruce ex Benth., *Ocotea petalanthera* (Meiss.) Mez, *Eschweilera paniculata* (O. Berg) Miers (Amaral et al., 2009).

Amafrutas and Mocambo fragments showed the largest concentration of species of late secondary succession – respectively, 53.8% (n = 325) e 50.7% (n = 234). Conversely, Trambioca Is. and Bosque Rodrigues Alves fragments concentrated the highest indices of pioneer species – respectively, 25.2% (n = 250) and 18.20% (n = 258) (Table 3).

### *3.2. Threatened species (Brazilian national list and Pará State list)*

Nine species officially listed as threatened by, respectively, the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) and Pará State Secretary for the Environment (SEMA/PA) were identified in the fragments studied (Table 4). Out of the 31 arboreal species threatened in the State of Pará, slightly over one-fourth (26%) were found in this survey. Three threatened species each occurred in only one fragment: *Mezilaurus itauba* Meisn. and *Qualea caerulea* Aubl. in Mocambo and *Tabebuia impetiginosa* (Mart ex DC.) Standl in Gunma. The remaining five species were common to two or more fragments. *Aspidosperma desmanthum* Benth. ex Muill. Arg. and *Manilkara huberi* (Ducke) Chevalier had the most widespread occurrence and was found in four and five fragments, respectively. In Combu Is. no threatened species were found, which was to be expected as it is strictly a floodplain environment, while almost all threatened species are typically of upland forests.

### *3.3. Conservation of fragments*

According to the parameters used (Table 5), areas that have achieved the highest sustainability score and therefore with more favorable scenarios for long-term conservation were Combu (22), Gunma (21) and Mocambo (20), followed

**Table 3.** Percentage distribution of species among successional groups of tree flora in six primary forest remnants in the metropolitan area of Belém, State of Pará, Brazil. Successional group classification based on Budowski (1965).

| Ecological group | Forest fragments | | | | | |
|---|---|---|---|---|---|---|
| | Amafrutas | Trambioca | Bosque | Gunma | Mocambo | Combu |
| Pioneer | 10.4 | 25.2 | 18.2 | 12.4 | 14.5 | 4.3 |
| Early secondary | 31.2 | 34.8 | 31.0 | 35.8 | 32.3 | 64.3 |
| Late secondary | 53.8 | 38.4 | 47.6 | 48.0 | 50.7 | 31.4 |
| Climactic | 4.6 | 1.6 | 3.2 | 3.8 | 2.5 | 0 |
| Total | 100% | 100% | 100% | 100% | 100% | 100% |

**Table 4.** List of threatened species found in six primary forest remnants in the metropolitan area of Belém, State of Pará, Brazil. Species are listed in the Normative Instruction of the Brazilian Ministry of Environment of September, 2008 (Brazilian National Flora); and in the Decree Nº. 802 of February 2008 (Pará State Flora), under the threat category "vulnerable".

| Species | Local popular name | Red list | Environment | Amafrutas | Trambioca | Bosque | Gumma | Mocambo | Combu | Nº. individuals |
|---|---|---|---|---|---|---|---|---|---|---|
| *Aspidosperma album* (Vahl) Benoist ex Pichon | Araracanga-preta | Pará | Várzea/ Terra Firme | 1 | | 2 | 1 | 1 | | |
| *Cedrela odorata* L. | Cedro-vermelho | Pará | Terra Firme | 1 | - | 33 | - | - | - | 34 |
| *Eschweilera piresii* S.A. Mori | Matamatá-jarani | Nacional/Pará | Várzea | 1 | - | - | 54 | - | - | 55 |
| *Euxylophora paraensis* Huber | Pau-amarelo | Nacional/Pará | Terra Firme | 9 | - | - | 1 | - | - | 10 |
| *Hymenolobium excelsum* Ducke | Angelim-da-mata | Pará | Terra Firme | 1 | - | - | 1 | - | - | 2 |
| *Manilkara huberi* (Ducke) Chevalier | Maçaranduba | Pará | Várzea/ Terra firme | 17 | 7 | 16 | 22 | 5 | - | 67 |
| *Mezilaurus itauba* (Meisn.) Taub. ex Mez | Itaúba | Pará | Várzea/ Terra Firme | - | - | - | - | 1 | - | 1 |
| *Qualea caerulea* Aubl. | Mandioqueira | Pará | Várzea | - | - | - | - | 1 | - | 1 |
| *Tabebuia impetiginosa* (Mart. ex DC.) Standl. | Ipê-roxo | Pará | Terra Firme | - | - | - | 2 | - | - | 2 |

**Table 5.** Scenarios of conservation of six primary forest remnants in the metropolitan area of Belém, State of Pará, Brazil. Based on: Viana and Pinheiro (1998). Scale factors of sustainability score: 0-10 (unfavorable), 11-15 (with favorable restriction), 16-25 (favorable).

| Forest fragments | Factors that influence biodiversity conservation | | | | | | |
|---|---|---|---|---|---|---|---|
| | Size of forest fragment | Access control/ surveillance | Connectivity with other fragments1[1] | Exploitation of natural resources | Type of neighborhood[2] | Sustainability score | Scenario of conservation |
| Bosque | 0 | 5 | 0 | 5 | 0 | 10 | Unfavorable |
| Mocambo | 5 | 4 | 5 | 3 | 3 | 20 | Favorable |
| Combu | 5 | 3 | 5 | 4 | 5 | 22 | Favorable |
| Trambioca | 5 | 0 | 5 | 0 | 4 | 14 | Favorable with restriction |
| Amafrutas | 5 | 4 | 3 | 3 | 3 | 18 | Favorable |
| Gunma | 4 | 4 | 5 | 4 | 4 | 21 | Favorable |

[1]This refers to the level of connection with other areas with vegetative cover. Trambioca and Combu fragments should, in theory, not be considered with respect to connectivity as they are islands. However, in both cases, the draining strip (rivers and streams) separating them from other surrounding fragments is very narrow (from 200 to 30 m in most places, respectively), allowing for animal crossings (particularly birds) and flora dispersal. Connectivity in the Bosque Rodrigues Alves was considered inexistent, as the park is completely surrounded by urban streets in downtown Belém. [2]Fragments that are limits (neighbors) with green areas or drainage (Combu Island) have better scores than fragments whose boundaries are urban areas and public roads (Amafrutas and Mocambo Reserve).

by Amafrutas (18). Trambioca Is. is even more vulnerable because there is no kind of access control or monitoring (Table 5). The Bosque fragment has no connectivity to other areas and its surroundings are highly urbanized and were considered unfavorable for long term conservation (Table 5).

Amafrutas and Trambioca Is. were found to be in a most distressing situation with respect to their conservation. Both those fragments are subject to all threats considered (real estate speculation, hunting and fishing, wood extraction and fragmentation). In Combu Is. the situation is particularly favorable: it is an island (therefore its access is somewhat hindered), and also an Environmental Protection Area. Nevertheless, it was found to still be threatened by hunting and fishing and wood extraction.

The survey showed that the Gunma fragment is relatively well preserved, with a high degree of integrity, and there is moderate connectivity and urbanization of the surroundings. No record of real estate speculation was found, despite reports of hunting and fishing and wood extraction and fragmentation. The good conservation of this fragment is in part explained by it being a private property with some access control and monitoring.

The Mocambo reserve fragment also benefitted from favorable conservation conditions. It is quite a significant area in physical dimensions (22 km$^2$), and practically within city limits (3 km). The degree of connectivity there is high, although the degree of integrity and urbanization of the surroundings is only moderate. Similarly to other fragments, some threats have been identified – in this case, hunting and fishing, wood extraction and fragmentation.

## 4. Discussion

The fragments studied constitute the most significant primary forest remnants in the metropolitan region of Belém (Leão et al., 2007; Pires and Salomão, 2007). They cover a surface area of 130.15 km$^2$ (excluding Trambioca Is. for its location outside the proper region), or 35% of the total area (369 km$^2$) of remnant forests in metropolitan Belém (Leão et al., 2007). In general, the studied fragments presented high diversity indices, as the ones between 3.83 and 5.85 are considered high in tropical forests (Knight, 1975). Combu Is. was an exception (2.58), as the vegetation there is strictly floodplain forest, the diversity is typically lower than in upland forests in Amazonia (Salomão et al., 2002; Almeida et al., 2004).

All threatened species are in the "vulnerable" category (IUCN, 2007). Those are timber species whose populations were significantly reduced in recent decades due to their disorderly exploitation: their average price (sawn wood for the domestic market) varies from US$ 144/m$^3$ (*Hymenolobium excelsum*) to US$ 316/m$^3$ (*Tabebuia impetiginosa*) (Lentini et al., 2005). More recently, the latter species underwent a sizeable increase in price, attaining a market value of over US$ 1,000/m$^3$ (sawn wood for export). Individuals of these threatened species, as well as of other more valuable timber such as *Mezilaurus itauba*, *Euxylophora paraensis* or *Manilkara huberi*, are practically restricted to areas with private access (Bosque, Mocambo, Gunma, Amafrutas). *Eschweilera piresii* is an exception among timber species for its even more restricted distribution. The material type was collected in 1977 in Granja Maratá in the municipality of Benevides (30km from Belém) from the property of botanist João Murça Pires. Its distribution is probably restricted to the Belém Center of Endemism (Mori and Prance, 1990), and therefore it calls for special attention for its conservation.

Other species listed as threatened in the State of Pará, and for which Belém is included in the geographical distribution

range, did not occur in the fragments surveyed. Some examples: *Aspidosperma album* (Vahl) Benoist ex Pichon (araracanga), *Centrolobium paraense* Tul. (porcupine tree or pau-rainha) or *Peltogyne maranhensis* Huber ex Ducke (purpleheart or pau-roxo). It is possible that in the studied remnant forests, the natural populations of these species underwent local extinction, particularly in the cases of *Aspidosperma album* and *Centrolobium paraensis* due to their history of lumbering or because of their own rarity in nature – as in the case of *Peltogyne maranhensis*, with only two records for the region, one in Belém and another in Mosqueiro Is. (Silva, 1976). On the other hand, *Bertholletia excelsa* (Brazil nut tree or castanheira), while not recorded in the fragments, was observed around Belém, mainly along the PA-150 highway. The population of this species has diminished considerably in recent decades (Salomão et al., 2006). *Virola surinamensis* (Rol. ex Rottb.) Warb. has excellent populations in the Mocambo and Combu Is. and this reinforces the importance of conservation of these areas, even if the species is no longer threatened by exploitation pressure it suffered severe depression and reduced populations in the past (Maués, 2009; Jardim and Mota, 2007).

Among all parameters analyzed, fragmentation is the main threat to plants – and therefore also animal – conservation. Reduction in species population, change in migration and dispersal patterns and the resulting deterioration of biological diversity along a time scale are consequences of fragmented forest landscapes (Tilman et al., 1994). In small fragments, species with naturally low density can undergo considerable reduction in population size, becoming more vulnerable to local extinction due to stochastic, catastrophic or genetic demographic events (Shafer, 1981). This could be happening to some of the species studied, with at most two individuals and recorded in the smallest fragments (Bosque Rodrigues Alves, 15 ha; Gunma Park, 400 ha). Such is the case, for instance, of *Guarea macrophylla* Vahl (andirobarana), *Albizia niopoides* (Spruce ex Benth.) Burkart (paricarana), *Ecclinusa abbreviata* Ducke (abiu-balata) or *Pouteria campanulata* Baehni (abiu) in Bosque, and *Couratari tenuicarpa* A.C. Sm. (tauari), *Manilkara bidentata* (A. DC.) A. Chev. (maparajuba) or *Pouteria elegans* (A. DC.) Baehni (abiu) in Gunma Park. Although the rarity is a phenomenon known for the Amazonian forest (Pires and Prance, 1985; Pires and O'Brien, 1995), it can be additively influenced by the sample universe, which explains the high number of rare species in the Trambioca fragment, which is the smallest area inventoried in this study (2 ha).

Along with the populational question, another matter which should be addressed is the late secondary succession and climatic species (sensu Budowski, 1965) usually dispersed by animals (Roosmalen, 1985; Carvalho, 1992). These are in the most serious situation with respect to the degree of threat, compared to species with large populations less adapted to stress conditions and such gaps are caused by environmental exploration and therefore less at imminent risk. Species in such a highly critical condition include, for instance, *Copaifera duckei* Dwyer (copaíba), *Hymenaea courbaril* L. (jatobá), *Peltogyne venosa* (Vahl) Benth. (purpleheart or pau-roxo), *Bowdichia nitida* Spruce ex Benth. (sapupira or sucupira-amarela), *Hymenolobium excelsum* Ducke (Para angelim or angelim-da-mata), *Mezilaurus itauba* (Meisn.) Taub. ex Mez (itauba), *Brosimum potabile* Ducke (sande or amapá-doce).

Further cause for concern is a species occurring in isolation in given fragments, such as *Aspidosperma eteanum* Markgr. (araracanga), *Trattinnickia glaziovii* Swart (breu-sucuruba), *Lecythis holcogyne* (Sandwith) S.A. Mori (matamata-jarani) and *Ocotea fasciculata* (Nees) Mez (moena or louro-preto), all in Amafrutas. Similarly, in Gunma Park the following are found *Tabebuia impetiginosa* (Mart. ex DC.) Standl. (pink ipê or ipê-roxo), *Peltogyne venosa* (Vahl) Benth. (purpleheart or pau-roxo), *Couepia robusta* Huber (pajura), *Aniba riparia* (Nees) Mez (louro) and *Manilkara paraensis* (Huber) Standl. (maparajuba). The species *Maytenus myrsinoides* Reissek (axixuá), *Apuleia molaris* Spruce ex Benth. (amarelão), *Guarea macrophylla* Vahl (andirobarana) and *Qualea dinizii* Ducke (mandioqueira) were recorded in Bosque Rodrigues Alves. The vulnerability of these occurrences in isolation is aggravated by threats to the conservation of the fragments: such is the case in particular of Amafrutas, under a severe process of loss of vegetative cover. This remnant is located in an area of urban expansion in metropolitan Belém (along the BR-316 highway) and is being intensely invaded recently for purposes of land development and housing.

Primary forest fragments comprise an important habitat for hundreds of plant and animal species absent from, or able to very slowly colonize, secondary forests (Vieira et al., 2005, 2007; Barlow et al., 2006). The fragments studied are relevant for the conservation of species. In them, over half of the species are of late secondary succession (except for the island fragments of Trambioca and Combu due to the intense process of logging), which are able to recolonize secondary forests in man-altered landscapes such as the areas investigated.

Based on the factors that affect biodiversity conservation in forest fragments analyzed in this study, the results show that: 1) the fragment of the Bosque presents an unfavorable scenario for conservation, 2) the fragment of the island Trambioca presents a favorable environment with restriction because the exploitation of natural resources and lack of monitoring and access control, 3) the remaining fragments show a favorable scenario for conservation, in order of conservation are Combu, Gunma, Mocambo and Amafrutas.

A better understanding of the fragmentation process (sensu Fahrig, 2003) and associated factors such as the multiplication of creeping species, the extension of the border effect and the increase in mortality and recruitment rates (Laurence et al., 1998), as well as further similar inventories involving other elements of the biota (for instance, plants of other habitus and animals), are important in defining conservation and restoration strategies for those fragments.

We suggest emergency actions be taken by Municipal, State and Federal environmental agencies to implement

management plans for the already existing Conservation Units (UCs in Portuguese), the creation of new UCs in areas of primary forest fragments, such as the Amafrutas Reserve and the reinforcement of actions of surveillance and monitoring.

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