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Composition and richness of woody species in riparian forests in urban areas of Manaus, Amazonas, Brazil

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HIGHLIGHTS

- Woody plant species composition in urban Amazon watersheds is proposed.
- The number of exotic species is low in the urban riparian vegetation.
- Fruit plants are the most abundant species either exotic or native.
- The urban watersheds have similar plant community composition.

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ABSTRACT

We studied the riparian vegetation distributed across four watersheds in urban areas of Manaus, Amazonas—Brazil in order to compare native and exotic plant community patterns. In total, we investigated the woody plant communities in 31 urban streams. The transects established in each site were of an area 200 m long × 5 m wide parallel to the stream, giving a total study area of 3.1 ha. Exotic species accounted for 15% of the total of 126 species identified. Our results showed absence of significant differences in species richness and diversity between basins suggesting that vegetation of urban streams located near more urbanized areas is not yet seriously compromised. We found a low percentage of non-native species with relatively high woody species diversity. However, we recommend the correlation of variable such as ecological strategies, species lifespan, species richness, and species cover with environmental data to provide elements for impact assessment and the monitoring of these watersheds.

1. Introduction

The disordered and accelerated growth of large urban centres threatens the existence of our ecosystems (Güneralp & Seto, 2013; McDonald, Marcotullio, & Güneralp, 2013; Tredeci, 2010). As cities grow, large areas of primary forest are reduced to small fragments, leading to loss of biodiversity (Laurence, 2010) and an increase in biotic homogenisation (McKinney, 2006), and limiting the growth and succession of perennial species (Rebele, 1994). Consequently, community structure can change completely and permanently, with an impact on nutrient cycles and other key ecosystem processes (England & Rosemond, 2004).

Because they offer a means of transport, easily available food, and a ready-made waste disposal system, rivers and streams become a natural focus in the urbanisation process (Pauchard, Aguayo, Penã, & Urrutia, 2006), and their ecosystems are often the most seriously affected. In general, the main disturbances include increased sediment deposition, eutrophication, logging, grazing and trampling (Planty-Tabacchi, Tabacchi, Naiman, Deferrari, & Décamps, 1996). Such disturbances often occur in concert with, or act as triggers for, the proliferation of non-native plants (Richardson et al., 2007).

In degraded riparian zones, invasive exotic species are often responsible for an increase in water uptake, soil salinisation and native habitat changes (Tickner, Angold, Gurnell, & Mountford, 2001; Zavaleta, Hobbs, & Mooney, 2001). Some invasive species are also more combustible and can increase the susceptibility of

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riparian areas to damage from fire, with a consequent destruction of native species (Brooks et al., 2004) and the creation of more favourable conditions for exotic species. The likelihood of invasion by exotic species is increased in altered environments such as areas bordering those forests that have suffered a reduction in the density of branches, twigs and leaves, exposing the forest interior (Cadenasso & Pickett, 2001). Furthermore, the proportion of exotic species appears to be increasing more in urban areas than in agricultural or forested areas, in response to alterations attributable directly or indirectly to human activity (Duguay, Eigenbrod, & Fahrig, 2007).

In spite of the evidence of the negative impact of exotic species, the invasive potential of these plants is a controversial issue, since their presence may often be a symptom rather than a cause of environmental degradation (Richardson et al., 2007). A relationship between exotic species presence and reduction of diversity in riparian environments is widely accepted (Burton, Samuelson, & Pan, 2005; Slobodkin, 2001). However, in certain circumstances it is the dominance of some competitive species that is the main determinant of plant diversity, regardless of whether they are native or exotic (Hejda & Pysek, 2006; Maskell, Bullock, Smart, Thompson, & Hulme, 2006). Perhaps surprisingly, the factors that favour elevated levels of richness in riparian zones are almost always the same as those that facilitate invasion by exotic species, and which promote the success of these species in more disturbed areas (Tabacchi & Planty-Tabacchi, 2005).

In Amazonia, deforestation (principally that due to the substitution of native forest with pasture) is considered the main factor responsible for loss of and reduction in the environmental integrity of streams (Bleich, Mortati, André, & Piedade, 2014; Bleich, Piedade, Mortati, & André, 2015; Neil, Deegan, Thomas, & Cerri, 2001; Thomas, Neill, Deegan, Krusche, Ballester, & Victoria, 2004). The streams of urban Manaus have suffered severely with organic pollution caused by domestic waste, which often results in the eutrophication of the waterways (Couceiro, Hamada, Luz, Forsberg, & Pimentel, 2007; Monteiro-Júnior, Juen, & Hamada, 2014). In addition, increased insolation resulting from the removal of native vegetation has resulted in the uncontrolled spread of some aquatic plants, particularly exotic grasses (Piedade et al., 2010).

On this basis, it would be logical to consider that riparian vegetation in urban Manaus may be suffering alteration, given that anthropogenic disturbances make the plant community more susceptible to invasion by exotic plant species (Burton et al., 2005). However, there are no data on the structure and distribution of native and exotic species, so that an evaluation of the relationship between change in plant cover and loss of environmental integrity along streams in urban Manaus is very difficult. The objectives of our study were therefore (i) to describe the composition and diversity of woody plant species present in the urban streams of the city of Manaus, evaluating the pattern of native and exotic species; and (ii) to understand the pattern of community structures across different watersheds.

2. Materials and methods

2.1. Study area

Manaus, capital of the state of Amazonas, is the largest city in the North of Brazil, covering an area of approximately 11,400 km^2 and with a population density of 158.06 people per square kilometre. The city has experienced significant growth in the past forty years, with a population increase from just 171,343 in 1960 to 1,802,535 in 2010 (IBGE, 2010).

The study covered the period between November 2011 and August 2012 in the Manaus urban area (03°08′S 60°01′W), at an altitude of 21 m above mean sea level, situated within the Central Amazon mesoregion in Northern Brazil. Its geomorphology is described by a shallow plateau along the left margins of the Negro River. The local climate is characterised by a wet season with significant rainfall between January and May, and a moderate dry season from June to December, with a few months where rainfall is less than 100 mm. The average annual temperature is 26.7 °C and annual rainfall of 2420 mm (Alvares, Stape, Sentelhas, Gonçalves, & Sparavek, 2014).

According to the Brazilian Ministry for the Environment, the urban area of Manaus covers four distinct watersheds, which form part of the larger Negro and Amazon river basins. Two of the watersheds – Educandos and Mindú – are entirely within city limits, while the other two are found within the urban areas Tarumã and Puraquequara (Fig. 1). The Educandos hydrographic basin covers an area of 44.87 km^2 in the southeast part of Manaus. It comprises several tributaries, the largest being the Quarenta stream (Educandos, 8 km long), which flows in a northeast/southwest direction. The Mindú basin has an area of approximately 117.95 km^2, with its main tributary being the Mindú stream (20 km long), flowing in the same direction as the Quarenta. The Tarumã basin covers 1,353.27 km^2, and its principal tributary is the Tarumã stream, originating to the north of the city and extending 42.11 km to the south. Finally, the Puraquequara basin covers an area of 151.73 km^2, and has as its main tributary the Puraquequara stream of 19.54 km, flowing south from the northeast of the city (Fig. 1; Appendix A).

The waters of the Educandos and Mindú watersheds have a higher pH, increased conductivity, lower dissolved oxygen content, and higher cation and anion concentrations than those of other watersheds in the region (Melo, Silva, & Miranda, 2006). The tributaries that comprise the Tarumã and Puraquequara basins, in their undisturbed state, are classified as black-water streams with low pH and low electrical conductivity, having sandy riverbeds with accumulated organic material derived from the marginal vegetation typical of the region (Couceiro et al., 2007).

Undisturbed, the riparian vegetation comprises dense tropical forest, with trees of a height of between 20 and 30 m. The dominant tree species is *Mauritia flexuosa* (buriti), which forms an almost homogeneous vegetative cover known as "buritizal". Other species are frequently encountered, especially *Caryocar microcarpum*, *Clusia* sp. (apuí), *Vitex spongiocarpa*, *Virola divergens*, *Socratea exorrhiza*, *Oenocarpus bataua*, *Iryanthera juruensis*, *Bellucia dichotoma*, *Protium hebetatum*, *Virola pavonis*, *Symphonia globulifera* and *Eschweilera bracteosa*.

2.2. Sampling design

Using digital topographic maps, we selected 31 first- and second-order streams (Fig. 1), distributed as follows: Puraquequara (five streams), Tarumã (seven streams), Educandos (nine streams) and Mindú (10 streams). They are all "igarapés de terra firme" (upland streams) that are not affected by the flood pulse that characterises the major rivers of the region. We used a robust randomization procedure to ensure good representation of streams within each watershed. Random numbers were assigned to each stream that met selection criteria, and 40 stream sites were selected (10 streams for each watershed). Field visits determined that 9 of the 40 sites were inaccessible, and were therefore not suitable for study. Data were collected from the remaining 31 sites. All streams were at least 2 km apart and situated typically in residential/commercial areas. The transects established in each site were of an area 200 m long × 5 m wide, parallel to and one metre distant from the stream, giving a total study area of 3.1 ha.

For each transect, the number of trees with a DBH (diameter at breast height) ≥10 cm was recorded, together with the tree species where possible. Fertile specimens were collected (collector