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Space and seasonality effects on the aquatic macrophyte community of temporary Neotropical upland lakes

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ABSTRACT

Temporal and spatial scales are key factors that affect species distribution. Temporary lakes may be intensely affected by both scales, and the aquatic macrophyte community can rapidly respond to such environmental changes. Here, we investigate 26 Neotropical temporary upland lakes and describe the species richness and composition as well as the species richness within functional groups and the functional composition of aquatic macrophytes to better understand the effect of spatial and temporal scales on these attributes. Additionally, we highlight the scenarios where we found rare and endemic species during sampling. Our findings mainly suggest that spatial and temporal scales do not affect the total species richness or species richness within the functional groups. However, the temporal scale affects the species composition and functional-group composition. The species composition changes between dry and rainy seasons (beta-diversity), and such change was less dramatic six years after the first sampling. The identical pattern was found for the functional-group composition (functional beta-diversity). We also found small or few endemic species populations that co-occurred with potentially invasive species, which could threaten endemic species and lead to global extinctions. Finally, we suggest that the temporal dynamics of temporary lakes are fundamental in maintaining regional biodiversity. However, this dynamic may change over time by moving towards a future with a more homogeneous aquatic macrophyte assemblage, what may create a scenario with more functionally redundant species. Subsequently, applied ecological studies in such environments to better understand the temporal dynamics of the aquatic macrophyte community may help to improve future proposals of biodiversity management and protection.

1. Introduction

Several environmental factors affect the spatial (e.g., Chappuis et al., 2014) and temporal (e.g., Neiff et al., 2014) distributions of aquatic macrophytes. Spatially, water characteristics such as the presence of underwater light determine the distribution of submerged macrophytes, whereas, nutrient availability affects the free-floating species (Camargo et al., 2003; Bini et al., 1999). In addition, the spatial scale may also affect species distribution in general because of the differences in the distance between source and habitat (MacArthur and Wilson, 1967; Simberloff and Wilson, 1969).

The temporal scale or seasonality may determine the availability of areas for colonisation, which affects the species distribution (Ricklefs and Lovette, 1999; Neigel, 2003). For example, during dry seasons, aquatic systems may decrease the water column, which provides better conditions for amphibian aquatic macrophyte colonisation instead of for submerged species. Thus, environmental factors determine the species distribution and the distribution of functional groups of aquatic macrophytes (Mormul et al., 2010).

In tropical regions, isolated and shallow temporary upland lakes that are shaped on a lateritic crust have dramatic seasonal

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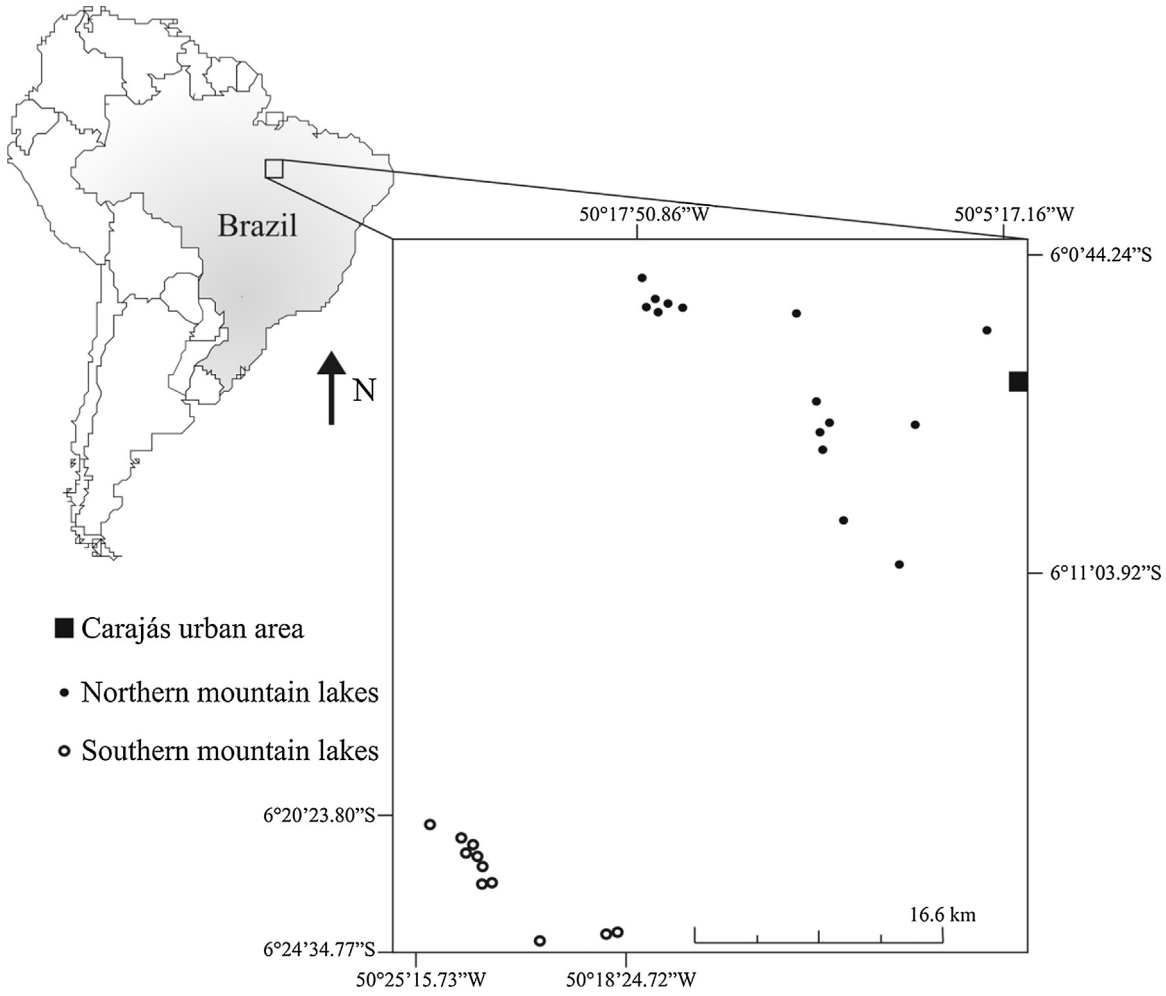

Fig. 1. Map of the sampled lakes categorized in northern and southern mountain ranges.

water level variation and become more similar to terrestrial habitats during the dry season, when the area of hydromorphic soil increases, and the water volume decreases to a small pool. However, when the long wet season arrives, the lake level rises again due to the great amount of rain and the concave orography that allows water accumulation. This type of temporal variation directly affects the ecological community attributes such as the density and composition of benthic invertebrates (Ogbeibu, 2001), diversity of zooplankton (Vignatti et al., 2012) and species richness of aquatic macrophytes (Della Bella et al., 2008).

Particularly for aquatic macrophytes, temporary lakes have distinct strong effects on the community attributes compared with those of perennial lakes (Della Bella et al., 2008), which have higher species richness in the Mediterranean region (Chappuis et al., 2014) and endemic taxa in the North American region (Björk and Dunwiddie, 2004). The seasonality of temporary lakes may affect the species distribution and maintain different macrophyte functional groups in a gradient of water depth (Fernández-Aláez et al., 1999). Despite low levels of successional change and differences between the local and regional plant diversities that may be found in Mediterranean temporary wetlands (Bagella et al., 2011), the seasonality enables the occurrence of dissimilar species composition (Fernández-Aláez et al., 1999), which potentially increases the regional diversity of fast-growing aquatic macrophytes.

The Neotropical region presents the highest diversity of aquatic macrophytes, more than 60% of which are endemic (Chambers et al., 2008). Even when the scale is reduced, one river basin in South America may support approximately 10% of the endemic aquatic macrophyte species from the Neotropics (Ferreira et al., 2011). The Neotropics are rich in aquatic environments and number of aquatic macrophyte species (e.g., Junk and Piedade, 1993a,b; Costa Neto et al., 2003) and is apparently underexplored regarding the aquatic macrophyte community structure and endemic aquatic macrophyte species, mainly in the temporary upland lakes.

Aquatic macrophytes are key organisms for management and conservation purposes (e.g., Akasaka et al., 2010; Chappuis et al., 2011), because they respond to environmental variations in space and time, and temporary lakes are unique and may display a high biodiversity (Chappuis et al., 2014). We sampled 26 Neotropical upland temporary lakes to test whether space and seasonality may determine the species composition, richness and functional groups of aquatic macrophytes in such environments. Additionally, we verified the effect of time on the species and functional beta-diversity, and highlighted the scenario where we found rare and endemic species during sampling.

2. Material and methods

The studied area is the National Forest of Carajás-Pará, Brazil, which is an Amazonian region rich in upland lentic water bodies with an average altitude of 710 m. The sampled lakes are characterised as temporary upland lakes with elevated aquatic macrophyte coverage. The climate in the region has an annual average temperature of 25 °C and a long period of rain (Lopes et al.,