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BIODIVERSITY VIEWPOINT

WILEY Diversity and Distributions

Protected areas: A focus on Brazilian freshwater biodiversity

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Abstract

Brazil has a variety of aquatic ecosystems and rich freshwater biodiversity, but these components have been constantly damaged by the expansion of unsustainable activities. An array of different conservation strategies is needed, especially the creation of protected areas (PAs, hereafter). However, Brazil's PAs are biased towards terrestrial ecosystems and we argue that current PAs have limited efficacy in the protection of

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freshwater biodiversity. New PAs should better consider aquatic environments, covering entire basins, rivers and other freshwater habitats. We recommend ways to implement these PAs and provide guidance to avoid social impacts. Freshwater systems in Brazil provide essential goods and services but these ecosystems are being rapidly degraded and will be lost if not adequately protected.

KEYWORDS
conservation units, human impacts, indigenous land, inland waters, Neotropical region

1 | INTRODUCTION

Brazil has a large number of freshwater ecosystems, many of which have high biodiversity (Abell et al., 2008; Agostinho, Thomaz, & Gomes, 2005; Turtle Taxonomy Working Group, 2017) and endemism (e.g., Bertaco & Carvalho, 2010; Daga, Debona, Abilhoa, Gubiani, & Vitule, 2016). However, many of these ecosystems have been disrupted by human activities, threatening the maintenance of native biodiversity and ecosystem services. This scenario points to the urgent need for a variety of different conservation strategies in the scientific, educational and political realms (Azevedo-Santos et al., 2017; Karam-Gemael, Loyola, Penha, & Izzo, 2018; Pelicice et al., 2017).

Creation of protected areas (PAs, hereafter) in different regions of Brazil represented an advance for conservation policies (Mittermeier, Fonseca, Rylands, & Brandon, 2005), especially because they can prevent deforestation (Nolte, Agrawal, Silvius, & Soares-Filho, 2013). However, current PAs have limited efficacy in protecting freshwater biodiversity (e.g., Fagundes, Vogt, & De Marco, 2016; Frederico, Zuanon, & De Marco, 2018). The creation of PAs in Brazil was strongly based on terrestrial biota and the threats to them, in general ignoring aquatic species and ecosystems (Fagundes et al., 2016; Frederico et al., 2018).

In this short essay, we question the efficacy of Brazilian PAs (only Conservation Units) in protecting freshwater environments and associated biodiversity. We argue that new PAs, based on the current categories of the National System of Conservation Units (SNUC, 2000), should explicitly incorporate freshwater biodiversity. In addition, we provide some guidance for avoiding social conflicts that may emerge from the establishment of these new PAs. Finally, we stress the urgency of creation of new PAs in the face of the ongoing expansion of unsustainable activities and the progressive loss of Brazilian freshwater ecosystems and biodiversity.

2 | FRESHWATER BIODIVERSITY UNPROTECTED

Most Brazilian PAs were created to protect terrestrial biodiversity (mainly vegetation cover, and strongly focused on forests; Overbeck et al., 2015). In the Brazilian Amazon, approximately 60 million hectares are protected but studies indicate that PAs have limited value for freshwater chelonians (Fagundes et al., 2016) and stream fishes (Frederico et al., 2018). In addition, the decline of large migratory fishes (e.g., Petrere, Barthem, Cordoba, & Gomez, 2004; Castello et al., 2013; Correa et al., 2015) indicates that existing PAs are not enough to maintain population dynamics and fisheries stocks. These fishes demand large areas to complete their life cycles, posing a challenge to conservation policies. Amazon PAs are, in general, vast ("mega-reserves", sensu Peres, 2005), but covering large forested areas does not automatically protect their freshwater biodiversity (Fagundes et al., 2016; Frederico et al., 2018).

In Brazil's southeast region, PAs are also biased in favor of protecting terrestrial biodiversity. In this region, where different biomes are found but most of its native vegetation has been removed, PAs "typically comprise hilltop areas and therefore exclude a large number of species that are not present in this type of environment" (Pompeu, Reis, Gandini, Souza, & Favero, 2009:665). Such a scenario excludes most freshwater habitats and their biota, with the possible exception of the smallest headwater streams. This situation does not necessarily apply to all regions of the country (e.g., Amazonia), but it represents another failure of the current conservation strategies in Brazil.

From a freshwater perspective, the most important limitation is that existing PAs, in general, cover only short stretches of river systems (Figure 1) or, in some cases, a small fraction of their headwaters. This pattern conflicts with the nature of fluvial networks, which are dynamic hierarchical macro-systems that strongly depend on connectivity to maintain their ecological integrity (Grant, Lowe, & Fagan, 2007; McCluney et al., 2014). Distant locations (i.e., habitat patches) are connected by fluvial watercourses, in which species disperse and occupy different habitats throughout their life cycles. In addition, local disturbances may propagate along the watercourses, especially in the downstream direction. This means that human actions in a river basin can spread through the system and affect any PAs that have been established (Saunders, Meeuwig, & Vincent, 2002), making the entire system vulnerable to anthropogenic actions occurring at different locations (e.g., pollution, mining, overfishing, damming). PAs that cover only segments of a river cannot secure the integrity, heterogeneity and dynamism of fluvial networks, which potentially threaten most freshwater organisms.

Restricting the protection to river segments does not allow maintenance of system functionality and complex biological dynamics. Migratory species, including some fishes, have complex

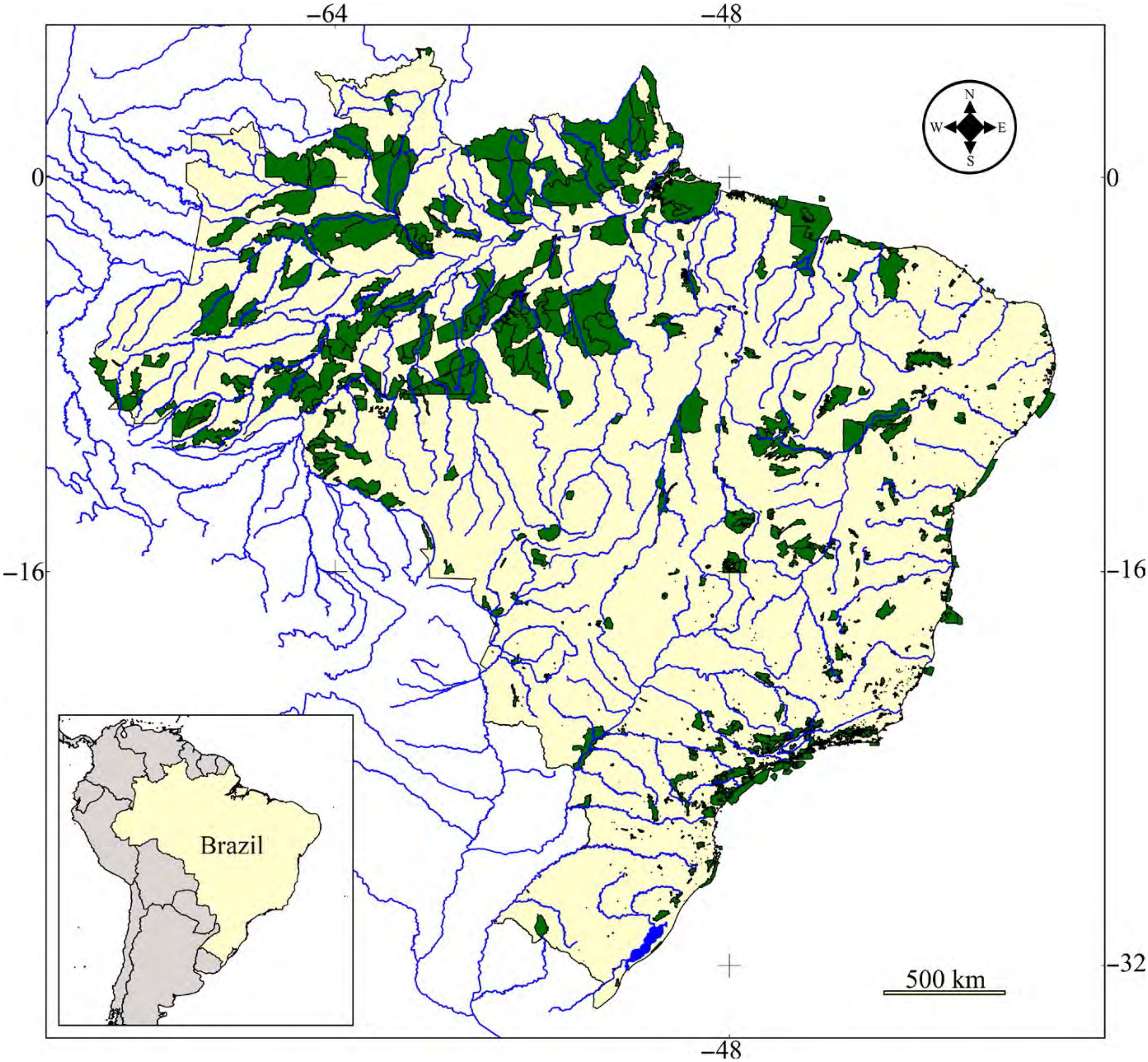

FIGURE 1 Protected areas (Conservation Units) and main Brazilian rivers. The shapefile "Conservation Units (all)" (MMA, 2018) and the shapefile "Principal Rivers" (sensu ANA, 2018) were used to the map, which was constructed using Quantum GIS (QGIS Development Team, 2018)

life cycles that demand spatial heterogeneity, that is, a diversity of habitats and specific conditions (e.g., Carolsfeld, Harvey, Ross, & Baer, 2003). The natural flow regime is another important function that single PAs cannot preserve because flow dynamics depend on a number of variables acting at the regional scale (Humphries, Keckeis, & Finlayson, 2014). For the Amazon basin, Castello et al. (2013:223) argued that "The protected area network provides protection against overharvesting and riparian deforestation, but does not protect freshwater ecosystems from the far-reaching impacts of dams". Impoundments have such effects in both upstream and downstream directions (see Agostinho, Pelicice, & Gomes, 2008), affecting the biodiversity in PAs. The invasion of non-native species is another challenge, because human activity (e.g., aquaculture) outside PAs introduces species that may reach PAs (Figure 2).

3 | PROTECTED AREAS FOR FRESHWATER BIODIVERSITY

3.1 | Focusing on freshwaters

The National System of Conservation Units ("SNUC" in Portuguese) set the guidelines for most of the country's PAs (known as "Conservation Units" [SNUC, 2000]). In principle, PAs in all categories of the SNUC could be established to protect freshwater biodiversity. For instance, the category "Wildlife Refuge" (*Refúgio de Vida*

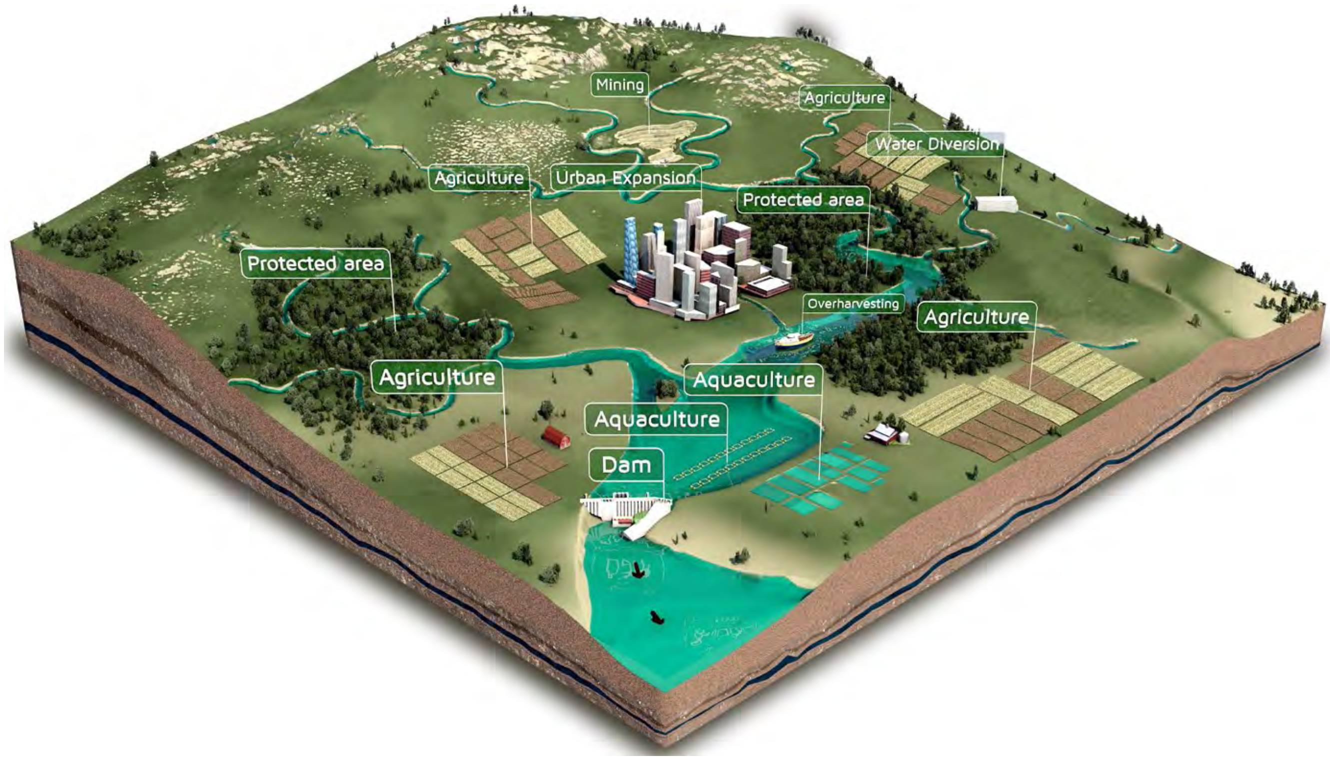

FIGURE 2 Hypothetical illustration showing how local PAs are inefficient for protecting freshwater biodiversity in river systems that are subjected to several human disturbances

Silvestre") could be used to preserve critical habitats for migratory species (e.g., spawning and nursery grounds) and other areas with essential functions for aquatic species (e.g., ponds, lakes and floodplains). A detailed analysis is needed to reveal how each PA category applies to different freshwater ecosystems, as well as the need for new categories. Here we just explore two approaches that may initiate the discussion about freshwater PAs in Brazil, which may be applicable to other countries with high levels of freshwater biodiversity. The first approach should be combined with the second, since they complement each other.

The first approach concerns the features of waterbodies or basins to be protected. We suggest, as a first step, protecting: (a) areas relevant for migratory species (whether threatened or not), (b) areas with endemic or threatened species and/or (c) areas with high biological diversity (taxonomic, functional and/or phylogenetic). Systematic conservation planning can indicate biodiversity gaps and priority sites for the development of PAs and other conservation strategies (Fearnside, 2015; Fearnside & Ferraz, 1995; Fonseca & Venticinque, 2018). The Brazilian government has adopted systematic planning (MMA, 2016), but as usual, they are biased towards terrestrial biodiversity. This is a global trend, since there are few studies that propose systematic planning for inland aquatic ecosystems (e.g., Carrizo et al., 2017).

The second approach is to consider the possibility of protecting entire basins (small to large). This measure is more desirable and would take into account all elements of a basin (e.g., watercourses, ponds, lakes, etc), in addition to functional aspects (e.g., the natural flow regime). If it is not possible to protect an entire basin, at least waterbodies such as rivers should be protected, including their entire length (i.e., headwaters to mouth) and adjacent areas (e.g., wetlands, upland buffers). Brazil has legal mechanisms, not included in the SNUC, to protect rivers; but this strategy has been rarely employed. For instance, law 15.082/2004 creates "permanent preservation rivers" ("*rios de preservação permanente*") that are valid in the state of Minas Gerais. This law represents a breakthrough in the protection of freshwater environments; it is clearly stated that entire rivers must be protected.

3.2 | Avoiding social impacts of new PAs

To avoid social impacts and conflicts, conservation policies should balance creation of restrictive (i.e., integral protection) and less restrictive (i.e., sustainable use) PAs. Protection of rivers and basins is more challenging than preservation of terrestrial areas. In Brazil and in many other countries, riverine resources sustain basic human needs, including those of indigenous and traditional populations. Implementation of fully PAs would lead to land expropriation and strict use restrictions, causing unacceptable levels of social impact. The severe social impacts of removing traditional people and of destroying their livelihoods are illustrated by recent hydroelectric dams on the Madeira (Fearnside, 2014) and Xingu Rivers (Fearnside, 2017; Magalhães & da Cunha, 2017). The SNUC includes "Integral-Protection Units" ("*Unidades de Proteção Integral*") and "Sustainable-Use Units" ("*Unidades de Uso Sustentável*") (SNUC, 2000), but the second category seems more appropriate for most river basins in Brazil. Artisanal fishing in tropical river systems, for example, is an important activity that tends to be irreplaceable but compatible with less-restrictive PAs. Appropriate management of sustainable-use units is therefore required to combine human activities with the protection of aquatic environments and their ecological functions. Combinations of different PA categories (i.e., geographical mosaics of Conservation Units) must also be evaluated. For example, headwater streams could be protected by integral-protection units, while important downstream reaches could be protected by sustainable-use units.

3.3 | Transboundary freshwater ecosystems

Major South American rivers run across national borders. This is the case of the Paraná, Paraguay and Uruguay rivers in the La Plata basin, which are shared by five countries (Argentina, Brazil, Bolivia, Paraguay and Uruguay). The same is true for several Amazonian tributaries, such as the Madeira, Purus, Solimões (Upper Amazon) and Japurá rivers. These cases will demand international agreements to implement effective PAs, otherwise poor conservation policies in one country will jeopardize protection efforts in another. For example, the ongoing hydropower development in Peru, Colombia and Bolivia (Finer & Jenkins, 2012) will have negative effects on floodplain ecosystems and fish populations in Brazil (Forsberg et al., 2017; Latrubesse et al., 2017; Lees, Peres, Fearnside, Schneider, & Zuanon, 2016). The presence of these macro-river systems in Brazil indicates that conservation efforts will depend on transboundary policies.

4 | THE NEED FOR MORE PAs

Brazil needs more PAs (Overbeck et al., 2015). However, these new areas should also consider freshwater environments and biodiversity because they are subject to a variety of human disturbances (e.g., Alho & Sabino, 2011; Vitule et al., 2015; Garcia, Ribeiro, Roque, Ochoa-Quintero, & Laurance, 2017). For example, a large number of small- and medium-sized dams have been planned or are under construction in Brazil and in other South American countries (Zarfl, Lumsdon, Berlekamp, Tydecks, & Tockner, 2015); hydropower expansion can irreversibly damage biodiversity and ecosystem functioning (Couto & Olden, 2018; Linares, Callisto, & Marques, 2018; Nogueira, Oliveira, & Britto, 2008; Winemiller et al., 2016).

In addition to dams, there are numerous other negative impacts caused by human activities that threaten freshwater biodiversity in Brazil. For instance, non-native freshwater species have been introduced for aquaculture or other activities for decades in the country (e.g., Magalhães et al., 2005; Coelho & Henry, 2017; Pelicice et al., 2017; Coelho, Fernandez, Cesar, Ruocco, & Henry, 2018; Gubiani et al., 2018), which can result in loss of native species and biotic homogenization (Mack et al., 2000; Simberloff et al., 2013; Vitule, Freire, Vazquez, Nuñez, & Simberloff, 2012). Other harmful actions, such as mining, have high impact on rivers (e.g., Fernandes et al., 2016; Tófoli et al., 2017), and existing PAs will be inefficient in protecting biodiversity from these perturbations.

Lastly we highlight that Brazil is one of the Latin American countries that has agreed to the "Aichi Biodiversity Targets", which list a series of goals for biological conservation worldwide (CBD, 2018). Establishing new PAs for freshwater systems is in accord with this treaty, specifically Target 11 (see CBD, 2018 for more details), and, therefore, Brazil needs to take appropriate measures to create these PAs.

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