Land Use Policy 99 (2020) 104851

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Land use in Brazilian continental wetland Ramsar sites

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ARTICLE INFO

Keywords:
Land drainage
Legislation
Protected areas
Urban development
Biome

ABSTRACT

Wetlands are systems of high biological diversity, productivity, and high economic and social importance to mankind. Despite its importance, wetlands are very threatened by human activities. World-wide, wetlands receive international recognition since 1971 by the Ramsar Convention. Guidelines adopted by Brazil to include its wetlands into the Ramsar List require that Ramsar sites are legally protected. This work analyses the main environmental pressures in the inner and surrounding areas of the 19 Brazilian inland Ramsar sites. Results show that wetland habitats are relatively well conserved in the inner areas of the 19 Ramsar sites. The proportion of natural landscape between the surrounding areas of Ramsar sites varies broadly (between 20 % and 99 %). Low anthropic disturbance inside of Ramsar sites suggests that external human pressures have not affected yet core areas of Ramsar sites. Brazilian guidelines to establish Ramsar sites only in protected areas has been very effective in Brazil, despite the many environmental pressures of protected areas, such as invasion by exotic species, tenure, human occupation, exploitation of illegal resources, etc.

1. Introduction

Wetlands are systems of high biological diversity, productivity, and high economic and social importance to mankind (Costanza et al., 1997, 2014; Seidl and Moraes, 2000; Gopal et al., 2000; Batzer and Sharitz, 2014; Junk et al., 2014). However, wetlands are highly threatened by human activities, causing a loss rate of around 60 % throughout the world (Millennium Ecosystem Assessment (MEA, 2005; Davidson, 2014). The extent of wetlands loss throghout Brazil is unknown (Junk et al., 2013), but at its southern, approximately 90 % of wetlands already suffer environmental pressure from human activities (Maltchik et al., 2017a, 2017b). The fast degradation of wetlands requires urgently policies to conserve these systems.

Today, one of the main strategies for biodiversity conservation is the establishment of protected areas (Chape et al., 2005), and in 2004, the Convention on Biological Diversity (CBD) estimated that at least 10 % of every world's ecorregion should be effectively protected by 2010. The Conference of the Parties (COP 10) stated that around 17 % of global surface should be protected by 2020 (Butchart et al., 2015). In Brazil, 20 % of the territory is protected by federal, state, and municipal conservation areas (Brasil, 2014), and 13.8 % as Indigenous Lands (Instituto Socioambental (ISA, 2016). However, spatial distribution of protected areas is irregular, not guaranteeing protection to all biomes and important sites, i.e., while 28.5 % of the Amazon area is protected, the proportion of protected areas in other biomes is much lower, i.e. Atlantic Forest (10.3 %), Pantanal (4.6 %), and Pampa (2.8 %) (Brasil, 2018). The percentage of Protected Areas by biome varies in Brazil (2.63 % - Pampa; 27 % - Amazon; 6,8 % - Atlantic Forest; 8.1 % - Cerrado; 4.6 % - Pantanal).

The widespread of laws for overall nature protection throughout the world is not specificically the case of wetlands. These are usually protected by laws aiming at other purposes, such as the Clean Water Act in USA (Mitsch and Gosselink, 1993) and the Water Framework Directive in the European Union (Gammeltoft and Murphy, 2007). At the international scope, world's wetlands receive international recognition since 1971 by the Ramsar Convention on Wetlands of International Importance (Ramsar Convention, hereinafter), which i) requires that each contractor designates at least one wetland site within its territory for inclusion in the List of Wetlands of International Importance, ii) recognizes Ramsar sites as being of significant value not only for its country, but for humanity as a whole, iii) provides guidance to contractors on the management of Ramsar sites and guidance on the wise use of all wetlands, and iv) embodies the government's commitment to take the steps necessary to ensure that its ecological character is maintained and measures against their threats. The Convention entered into force in December 1975 and has been ratified by 169 countries already. Regarding surface area of Ramsar sites, Brazil absolutely prevails above other countries (i.e. 194,478.79 km^2), mainly due to the

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https://doi.org/10.1016/j.landusepol.2020.104851
Received 17 May 2019; Received in revised form 22 April 2020; Accepted 9 June 2020

inclusion of the extensive wetlands of the Amazon biome. This Convention does not punish any country that has not been successful in protecting wetlands included in the Ramsar List, but adds temporarily the site and country to a list of non-compliance with signed international agreements (i.e., the Montreaux List). However, the Ramsar Bureau provides technical support to countries with sites on the Montreaux list, in order to reverse damage and potential loss.

Brazil signature of the Ramsar Convention in 1993 involves that it is responsible for biodiversity data collection, classification of wetlands, and studies for its protection. The inclusion of wetlands in the Ramsar List helps Brazil to obtain support for research development, identifying priorities in the implementation of government policies, and access to funding for the management of these areas both at the national and international scopes (OECO, 2017). The 19 wetland sites that Brazil promoted to include in the Ramsar List until March 2018 (Brasil, 2017) are just a modest part of the 2301 Ramsar sites thoroghout the world (Ramsar, 2018). Guidelines adopted by Brazil on the inclusion of wetlands in its Ramsar List require that they are in protected areas (i.e., as Conservation Unit or, more recently, as Indigenous Lands). Neighbouring countries (e.g. Argentina, Colombia, Chile, Venezuela, Uruguay) also designate Ramsar Sites within additional protection, but it is not the rule, and there are also Ramsar sites which are not associated with protected areas in those countries (Ramsar, 2018). Brazilian Ramsar sites are spread throughout all national biomes, except the caatinga, amounting a total surface of 19,447,878.51 ha, which represents 4.4 % of the national territory. Like protected areas in general, distribution of Ramsar sites among biomes is extremely uneven, with 92.6 % of them located in the Amazon biome, while only 0.74 % of them are in the Pampa biome. The Rio Negro Ramsar Site, in the Amazon biome, is the world's largest Ramsar Site, with 12.2 million hectares. The percentage of Ramsar sites area by biome varies in Brazil (0.4 % - Pampa; 4.6 % - Amazonia; 0.25 % - Atlantic Forest, 0.3 % - Cerrado; 1,5% - Pantanal).

This work aims to analyse the main environmental pressures in the 19 Brazilian inland Ramsar sites, and to determine the land use (i.e., typology and landscape) inside the wetland and in the surrounding area (10 km belt) of the Ramsar sites. Our expectation is that Brazilian Ramsar sites suffer low environmental pressures by human activities since they are inserted inside of protected areas under Brazilian legislation. If this expectation is confirmed, we will discuss the role of including Ramsar sites in areas already protected by legislation.

2. Material and methods

For this study, we selected the 19 Ramsar sites established in Brazil until March 2018, which are distributed over five biomes (Amazon, Atlantic Forest, Cerrado, Pampa, and Pantanal) (Table 1, Fig. 1). As we deal with land use and landscape modification, only inland wetlands were considered, excluding marine sites. Land use was analyzed inside the 19 Ramsar Sites and in their buffer zones. We defined a buffer zone of 10 km, according to the 1990 Brazilian Federal Act no. 99.274 of the National Environmental Council (CONAMA). This act established that a buffer zone should be considered in a 10-km radius from a Protected Area, and that any activities that affect the biota need a special license from the local environmental agency (Perello et al., 2012). Five land use categories were taken into account, following the classification proposed by the IBGE (1999), i.e. *Forestry* = Planting of non-native tree species for commercial purposes, *Livestock* = Extensive and intensive system of raising cattle loose in a native or man-made pasture, *Agriculture* = Production of one or more vegetable species at a large scale for commercial purposes, *Farming* = Composed of agriculture and livestock, usually in small rural property, and *Urbanization* = Area with human constructions in a densified form.

The first step to reach our goals was to select the data base providing data on land use for all Brazilian biomes during the same period of time. Land use surveys carried out by the Probio Project (Brasil, 2006) vectorized the entire Brazilian territory, based on the interpretation of LandSat images (from 2002 to 2004), resulting in maps at 1:250,000 scale in shape file format. The Ministry of the Environment provides a shape file for all Brazilian Ramsar Sites, and we used these polygons. The Probio Project (Brasil, 2006) images of the Landsat 5 T M and Landsat 7 ETM + satellites which were used were obtained mainly in 2002 − 2004. In order to identify and delineate vegetation cover classes of Probio Project (Brasil, 2006) images, legends provided by the Brazilian Institute for Geography and Statistics (IBGE, 1992) were used. Two types of map projections were used for the images that were analysed. The Universal Transverse Mercator (UTM) projection was used for inside-wetland analysis, and the Lambert Projection to analyze the 10 km-wide wetland surrounding belt. ArcGis 10.2.2. Software was used for image analysis at 1:250,000 scale, selecting hectares as surface units, and calculating percentage of every land use class.

3. Results

Wetland habitats are well preserved inside the 19 Ramsar sites, with proportions of natural habitats ranging from 92.6 % to 100 % within the analyzed sites (Table 2). This is consistent with the low human pressure recorded, with proportions of anthropic area ranging from 0 to 16.2 %. Only three Ramsar sites suffer human pressures affecting more than 5% of its surface, i.e. the Área de Proteção Ambiental (APA, that stands for Environmental Protection Area) of Lagoa Santa, Baixada Maranhense APA, and Estadual de Guaratuba APA. These sites are Sustainable Use Conservation Units, within which some anthropogenic activities are legally allowed. These APAs are in the Amazon and Atlantic Forest biomes. Most common environmental pressures inside Brazilian Ramsar sites are livestock, forestry, farming, agriculture, and urbanization. The highest proportion of transformed wetland surface area were recorded in Lagoa Santa and Baixada Maranhense APAs due to livestock.

The percentage of natural landscape varied widely in the buffer zone of wetlands, ranging from 20 % to 99 % among the 19 Brazilian Ramsar sites analyzed. The percentage of transformed area was high in the buffer zones of four Ramsar sites, two of them located in the Pampa biome (i.e., 59 % in the Lagoa do Peixe National Park, and 36 % in the Taim Ecological Station), and two in the Atlantic Forest biome (i.e. 80 % in the Rio Doce State Park, and 42 % in the Lagoa Santa APA) (Table 3). The buffer zones of three other sites are significantly altered by human activities, i.e. 22 % in the Guaratuba state APA, 12 % in the Peruibe APA, and 20 % in the Baixada Maranhense APA (Table 3). The main environmental pressures observed in buffer zones are livestock, forestry, farming, agriculture, and urbanization. Livestock was the most common human activity on the buffer zones of Ramsar sites (e.g., in Rio Doce State Park, Lagoa Santa), while urbanization (e.g., in Lagoa do Peixe National Park), agriculture (e.g., in Taim Ecological Station), and forestry (e.g., in Rio Doce State Park) also had a significant percentage.

4. Discussion

The present study observed a low environmental pressure inside the 19 inland Brasilian Ramsar sites. The most common human pressures (such as livestock, forestry, farming, agriculture and urbanization) are associated with the local economy and the national economic trend (Domingues and Bermann, 2012). Human activities recorded in some Ramsar sites were allowed by Brazilian legislation, since Brazilian law allows the presence of residents and use of natural resources in some protected areas, i.e. the Sustainable Use Conservation Units. Nevertheless, our expectation that the Ramsar sites would be in a good conservation status was corroborated by our research.

Greater environmental pressures were observed in the buffer zone of seven Brazilian Ramsar sites. Surface of modified land vary from 35.2 % to 80 %, mainly because of agriculture, livestock, and urbanization. These results are worrying since wetlands' surrounding areas are

Table 1
Brazilian continental Ramsar sites studied distributed by biome.

Biome	Sites	Date of designation	Area (Ha)
Amazon	Área de Proteção Ambiental das Reentrâncias Maranhenses	11/1993	2.680.911
	Área de Proteção Ambiental da Baixada Maranhense	02/2000	1.775.036
	Parque Nacional do Cabo Orange	02/2013	657.328
	Parque Nacional do Viruá	03/2017	216.427
	Parque Nacional de Anavilhanas	03/2017	350.469,8
	Reserva Biológica do Guaporé	03/2017	600.000
	Reserva de desenvolvimento Sustentável Mamirauá	10/1993	1.124.000
	Rio Negro	03/2018	12.001.614,4
Pantanal	Parque Nacional do Pantanal Mato-Grossense	05/1993	135.000
	Reserva Particular do Patrimônio Natural SESC Pantanal	12/2002	87.871
	Reserva Particular do Patrimônio Natural Fazenda Rio Negro	05/2009	7.000
Cerrado	Parque Nacional do Araguaia – Ilha do Bananal	10/1993	562.312
	Lund-Warming/APA Carste de Lagoa Santa	06/2017	23.865,4
Pampa	Parque Nacional da Lagoa do Peixe	05/1993	34.400
	Estação Ecológica do Taim	03/2017	32.806,3
Atlantic Forest	Parque Estadual do Rio Doce	02/2010	35.973
	APA Cananéia –Iguape e Peruibe	09/2017	202.307
	APA de Guaratuba	09/2017	38.329,3
	Estação Ecológica de Guaraqueçaba	06/2017	4.370

supposed to buffer the pressures of human activities on protected wetland areas. The low environmental impact inside Ramsar sites indicates that human activities in their surroundings have not yet significantly affected the inner areas of the Ramsar sites. The 10 km-wide buffer zones that were delineated according Federal legislation of Brazilian Conservation Units (Brasil, 1990) is very controversial among ecologists; it may be enough to preserve small protected areas, but it is irrelevant in the case of large Ramsar sites, such as those located in the Amazon biome (Perello et al., 2012). The width of the buffer zones should be specific to each protected area, and specific case-by-case studies are required, considering mainly the wetland hydrologic caracteristics of each Ramsar site (Perello et al., 2012).

Agricultural activities found inside wetlands and in their buffer-zones cause important impacts on the natural landscape and its biodiversity. Deforestation for agropastoral activities suppress the natural vegetation and impact local fauna (Rodrigues, 1999). Besides, the use of water for agriculture in the buffer zones compromises the hydrological regime of Ramsar sites (Ramsar, 2014). Some Brazilian studies have

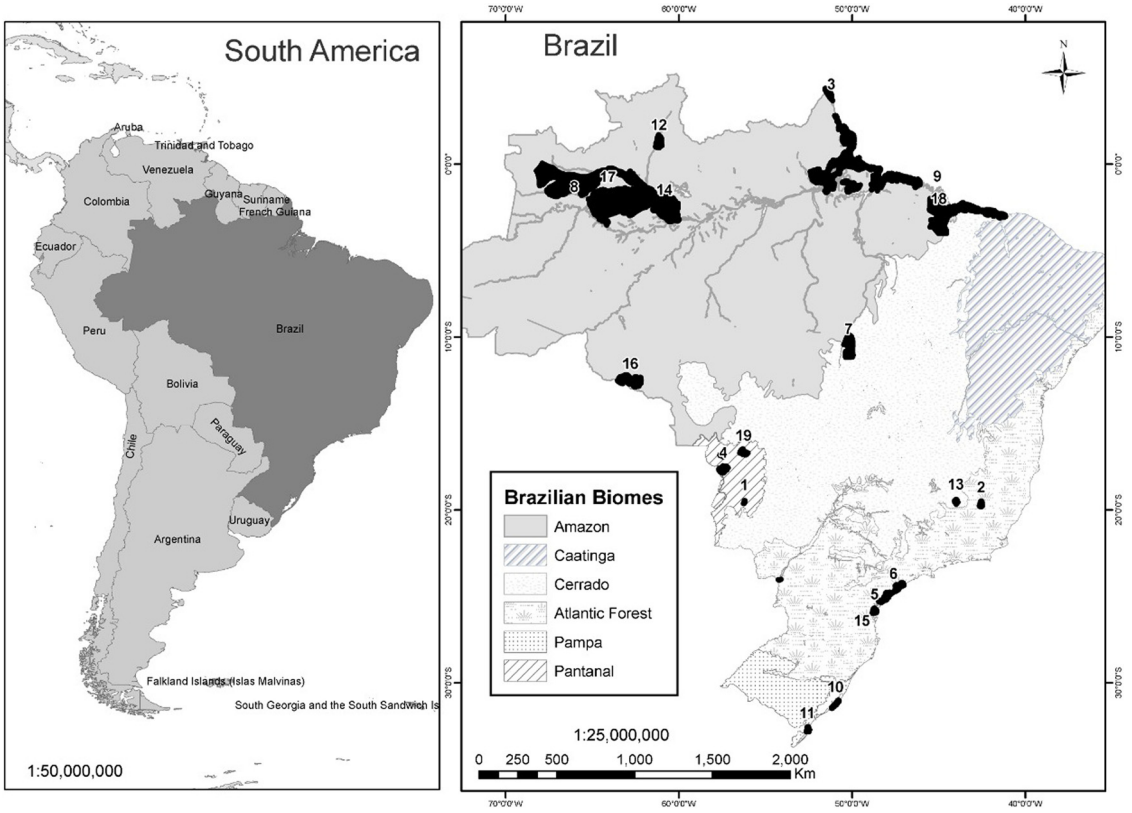

Fig. 1. Location of the 19 Ramsar sites distributed along the four Brazilian biomes. Ramsar sites are numbered as follows: 1. RPPN Fazenda Rio Negro, 2. Parque Estadual Rio Doce, 3. Parque Nacional Cabo Orange, 4. Parque Nacional Pantanal, 5. Estação Ecológica de Guaraqueçaba, 6. APA Cananéia-Iguape – Peruibe, 7. Parque Nacional do Araguaia, 8. Reserva de Desenvolvimento Sustentável de Mamirauá, 9. APA Reentrâncias Maranhenses, 10. Parque Nacional da Lagoa do Peixe, 11. Estação Ecológica do Taim, 12. Parque Nacional Viruá, 13. APA Lagoa Santa, 14. Parque Nacional de Anavilhanas, 15. APA Guaratuba, 16. Reserva Biológica do Guapore, 17. Rio Negro, 18. APA da Baixada Maranhense, 19. RPPN SESC Pantanal.

Table 2
Percentage of impacted area in the interior of each studied Ramsar site and the main human activities.

Ramsar site	Environmental pressure (%)	Human activities
Parque Estadual Rio Doce	3	*Urbanization, Livestock, Forestry*
Parque Nacional do Araguaia	0	–
Parque Nacional da Lagoa do Peixe	3	*Agriculture, Farming, Forestry*
Estação Ecológica do Taim	1.5	*Agriculture, Forestry*
Reserva Biológica do Guaporé	0.14	*Agriculture, Livestock*
Parque Nacional de Viruá	0.1	*Livestock*
Reserva de Desenv. Sustentavel de Mamirauá	0.002	*Agriculture*
Parque Nacional de Cabo Orange	0	–
APA Lagoa Santa	16.2	*Livestock*
RPPN Fazenda Rio Negro	1.3	*Livestock*
APA Reentrâncias Maranhenses	1	*Urbanization, Livestock*
Parque Nacional Pantanal Mato Grosso	0	–
APA da Baixada Maranhense	7.41	*Livestock, Urbanization, Farming*
Parque Nacional de Anavilhanas	0.01	*Indiscriminate*
Estação Ecológica de Guaraqueçaba	1.1	*Agriculture, Livestock, Forestry*
APA Estadual de Guaratuba	5.3	*Agriculture, Farming, Urbanizaton, Livestock, Forestry*
APA de Peruibe	3.9	*Agriculture, Farming, Forestry*
RPPN SESC Pantanal	0.8	*Livestock*
Rio Negro	0.63	*Agriculture, Livestock, Farming*

demonstrated the effects of agricultural on several wetland organism groups, such as invertebrates (Stenert et al., 2009), aquatic plants (Rolon and Maltchik, 2010), amphibians (Machado and Maltchik, 2010), reptiles and fishes (Carvalho et al., 2017; Quintela et al., 2019) and waterbirds (Guadagnin et al., 2012).

In Brazil, livestock have affected strongly the wetland biodiversity (Epele and Miserendino, 2015; Moreira et al., 2016) and it is the main cause of deforestation of Cerrado, Caatinga and Atlantic forest biomes, and it is now causing large deforestation in the Amazon forest (Silva, 2017). Agricultural activities are one of the main causes of deforestation in the Amazon, where most of the Brazilian Ramsar sites are located (Rivero et al., 2009). The loss rate of natural areas due to livestock rising in Amazon biome reaches 80 % in some regions (Domingues and Bermann, 2012). These researchers identified the strong expansion of soybean and livestock in southern Amazonia. This expansion is due to low land value, fiscal incentives, establishment of agroindustries, topography and soil physical conditions favorable to mechanization (Domingues and Bermann, 2012). However, the sites located in the Amazon Biome are relatively well conserved, including both the wetlands core and their surroundings, mainly because these sites are usually surrounded by mosaics of Protected Areas and indigenous lands.

ISA (2017) showed that the rate of deforestation in Amazon indigenous lands was 1.6 % in 2016, much lower than the average total percentage for the biome. According to WWF (2014), indigenous lands have acted as effective barriers against the expansion of forest transformation. A similar case occurs in the Pantanal and Cerrado Ramsar sites, where strong pressure from livestock is buffered by the mosaic of protected areas (Domingues and Bermann, 2012; World Wildlife Fund for Nature (WWF, 2017). The effects of forestry and urbanization on wetland biodiversity also have been documented on the last years in Brazil. Forestry influence the wetland invertebrate (Stenert et al., 2012), aquatic plants (Rolon et al., 2011) and anuran species (Machado et al., 2012). Urbanization strongly affects wetland invertebrates (Castello, 2010) and anuran species (Sievers et al., 2018).

5. Conclusion

Brazilian guidelines to establish Ramsar sites only in protected areas have been very effective in Brazil until now, despite the many impacts that protected areas are actually suffering, such as the invasion by exotic species, tenure, human occupation, exploitation of illegal resources, etc. The main environmental pressures observed in Ramsar sites were in accordance with the overall main environmental pressures observed in Brazilian protected areas by World Wildlife Fund for Nature (World Wildlife Fund for Nature (WWF, 2012), such as hunting,

Table 3
Percentage of impacted area in the buffer zone of each studied Ramsar and the main human activities.

Ramsar site	Impacted area (%)	Human activities
Parque Estadual Rio Doce	80	*Livestock, Urbanization, Forestry*
Parque Nacional do Araguaia	6.2	*Livestock*
Parque Nacional da Lagoa do Peixe	58.4	*Agriculture, Urbanization, Farming, Forestry*
Estação Ecológica do Taim	25.2	*Agriculture, Livestock, Urbanization, Forestry*
Reserva Biológica do Guaporé	8.8	*Agriculture, Livestock*
Parque Nacional de Viruá	4.5	*Agriculture, Livestock, Farming*
Reserva de Desenvolvimento Sustentavel de Mamirauá	3	*Agriculture, Urbanization, Farming*
Parque Nacional de Cabo Orange	0	–
APA Lagoa Santa	42.4	*Livestock*
RPPN Fazenda Rio Negro	4	*Livestock*
APA Reentrâncias Maranhenses	2.2	*Livestock, Urbanization*
Parque Nacional Pantanal Mato Grosso	1	*Livestock*
APA da Baixada Maranhense	19.3	*Farming, Urbanization, Livestock*
Parque Nacional de Anavilhanas	1.5	*Agriculture, Livestock, Farming*
Estação Ecológica de Guaraqueçaba	2.2	*Agriculture, Farming, Urbanization, Silvicuture*
APA Estadual de Guaratuba	21.6	*Agriculture, Farming, Urbanization, Silvicuture, Livestock*
APA de Peruibe	11.7	*Agriculture, Farming, Urbanization, Silvicuture*
RPPN SESC Pantanal	2.7	*Livestock*
Rio Negro	1.6	*Agriculture, Farming, Urbanization, Silvicuture*

biological invasions, livestock, logging, human occupation, agriculture, forestry, construction and operation of infrastructures, use of natural resources by residents, and mineral extraction. The establishment of Ramsar sites only in areas which are previously protected has guaranteed the protection of Brazilian Ramsar sites, but disregards the real impact on most Brazilian wetlands which have been altered by human activities in the last decades (Guadagnin et al., 2009; Machado and Maltchik, 2010; Maltchik et al., 2017a, 2017b; Stenert et al., 2018). Unfortunately, Brazilian protected areas are suffering drastic threats with the new policies implemented by the Brazilian administration since May 2019, mainly due to the weakening of environmental laws and institutions (Abessa et al., 2020; Ferrante and Fearnside, 2019; Levis et al., 2020). These changes put protected areas and biodiversity in all Brazilian biomes at risk, and it is very likely that conservation status of Brazilian Ramsar sites worsens.

CRediT authorship contribution statement

Soraya Ribeiro: Conceptualization, Methodology, Formal analysis, Writing - original draft. **Rafael G. Moura:** Formal analysis, Resources, Writing - review & editing. **Cristina Stenert:** Writing - review & editing. **Maximo Florín:** Writing - review & editing. **Leonardo Maltchik:** Conceptualization, Methodology, Resources, Writing - original draft, Writing - review & editing, Supervision, Project administration, Funding acquisition.

Acknowledgements

This study was funded by CNPq - Conselho Nacional de Desenvolvimento Científico e Tecnológico - (474892/2013-1). The PhD course of SR was funded by a CAPES scholarship. LM and CS hold CNPq Research Productivity grants. Glauber Zettler Pinheiro for English review.

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