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Diversity and distribution of anurans among different vegetation physiognomies in a savannah landscape in Central Brazil

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Abstract. The Cerrado is a domain considered priority for conservation and provides wide environmental heterogeneity, harbouring species with different ecophysiological needs. This landscape has been suffering several changes, and it is necessary surveys to better knowledge of local biodiversity. We conducted an inventory between 11 and 20 February 2011 and sampled different physiognomies in the northeast of Goiás State, Brazil. We found 27 amphibian species distributed in five families: Hylidae (12), Leptodactylidae (11), Bufonidae (2), Odontophrynidae (1) and Strabomantidae (1). We observed significant differences between forest and open areas species composition. Our study comprised species found in areas often neglected in studies contemplating this issue, such as anthropic use zones, especially for not being protected areas.

Keywords: Amphibia, biodiversity, Cerrado, environmental heterogeneity, inventory, richness

Introduction

Amphibians are a prominent group, with more than 7.000 described species distributed in almost all regions of the planet, except high northern latitudes, Antarctica and some oceanic islands (Frost, 2017). The most of species that occur in Brazil was described in the last 40 years and despite the increasing number of descriptions, our amphibian fauna is still underestimated and many species need to be descripted (Fouquet et al., 2013).

Amphibians play an important role in balance and maintenance of ecosystems due the intermediate position in food chain, acting as a link between primary producers and secondary consumers (Toledo et al., 2007; Wells, 2007). This makes essential to know the amphibian fauna of a region to understand its conservation state, as well as the ecological relationships existing there (Heyer et al., 1994). In addition, the knowledge about this group in a particular area may provide helpful basic data to support studies on biogeography, ecology, natural history and conservation efforts (Vasconcelos et al., 2014; Barata et al., 2016; Neves et al., 2017).

The Brazilian Cerrado is a savannah environment and one of the 34 biodiversity hotspot (Myers et al., 2000; Silva and Bates, 2002). It is the second large biome in Brazil, covering about 2 million km², which correspond to 23% of the total area of the country (Ratter et al., 1997). The term hotspot defines priority areas for conservation based on high biodiversity (1.500 endemic plant species, at least) and high threat degree (loss of 70% or more of the original vegetation) (Myers et al., 2000). The most recent estimate has shown that only 20% of the biome natural areas remain conserved (Scariot et al., 2005). The largest deforestation rates in the Cerrado reached an average of 1.5%, which represents the loss of three million hectares per year (Machado et al., 2004). These actions, mainly human, lead to a loss of biodiversity, especially of restricted distribution species, which have not been formally described yet (Diniz-Filho et al., 2005; 2009).

The Cerrado is formed by a savannah landscape and is composed by grasslands, gallery forests, deciduous and semi deciduous forests fragments (Eiten, 1977). This environmental heterogeneity offers conditions to species with different ecophysiological needs, which explains the richness and distribution of amphibian fauna through a mosaic of contrasting habitats, ranging from

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open and dry conditions to forest and humid, distributed side by side, with varying resources, influencing the dissimilarity of the amphibian community among the landscapes (Brandão and Araújo, 2001; Colli et al.; 2002; Nogueira et al., 2009).

More than 200 amphibians' species have been listed for the Cerrado (Valdujo et al., 2012), which already needs to be updated according to the new records and descriptions of new species in the last years (Colli et al., 2002). Our goal in this study is to describe the anurofauna diversity and its distribution throughout different savannah physiognomies in four study sites in Central Brazil, in the northeast of Goiás State, Brazil.

Materials and Methods

We conducted the fieldwork along the Flores de Goiás (14°27'20"S, 47°02'20"W), Alto Paraíso de Goiás (14°08'30"S, 47°31'16"W), Formosa (15°32'25"S, 47°20'14W) and São João da Aliança (14°42'22"S, 47°31'32"W) Municipalities, Goiás State (Fig. 1), in Central Brazil. The region presents an average altitude of 430 meters above sea level, and according to the Köppen classification, the climate is type AW, typical of tropical savannah, with wet summers and dry winters (Kottek et al., 2006). The mean annual temperature is 25.5º C and annual precipitation 1249 mm (http://pt.climate-data.org).

We performed the field sampling during diurnal and nocturnal periods between 11 and 20 February 2011, following the "Complete Species Inventories", "Visual Encounter Surveys" and "Audio Strip Transects" (Heyer et al., 1994). The staff consisted of 02 researchers who performed the field work in eight hours of search per day (four during the day and four at night), totalizing 160 hours of sampling in the sampling areas (16 hours-man/da x ten days of expedition). The environments that we sampled were chosen because they represent the Cerrado landscape and included anuran-breeding sites, such as ponds, marshes and swamps (Duellman and Trueb, 1994). We detected species directly (viewing or vocalization) or indirectly (e.g. presence of mortal remains, nests and spawns). Nine environments types were sampled in the study area: 1) Rice paddy (n=3); 2) Savannah (n=4); 3) Riparian forest (n=3); 4) Dry Forest (n=1); 5) Grassland (n=8); 6) Forest in regeneration (secondary forests; n=5); 7) Lowland (n=3); 8) pond/dam (n=5); and 9) anthropic use area (n=1).

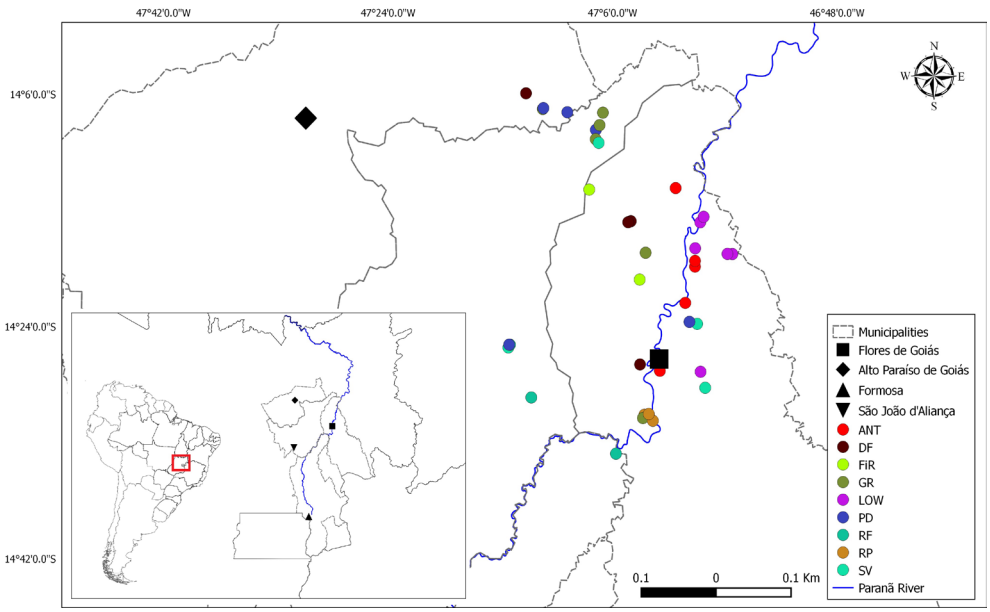

Figure 1. Map showing the sampled areas in the Cerrado (savannah landscape) of Flores de Goiás, Alto Paraíso de Goiás, Formosa and São João da Aliança Municipalities, Goiás State, Central Brazil. RP = Rice Paddy; SV = Savannah; RF = Riparian Forest; DF = Dry Forest; GR = Grassland; FiR Forest in Regeneration; LOW = Lowland; PD = Pond/Dam; ANT = Anthropic Use Area; CFG = City of Flores de Goiás.

We performed an accumulation curve using a presence-absence matrix (Gotelli and Colwell, 2001), through 1000 randomizations, wherein each column represents a species and each row represents one sampling site. We use species richness estimator Jacknife1 to determine the expected richness of amphibians (Colwell and Coddington, 1994; Colwell and Elsensohn, 2014). This analysis was performed using EstimateS v.9.0.0 (Colwell, 2000). We built graphs using Microsoft Excel (©Microsoft).

We conducted a non-metric multidimensional scaling (NMDS) through Jaccard index (Manly, 1944) to describe the different sampled physiognomy organization, and we determined the rate of stress to assess the distortion of ordering from the original data observed in the field. We construct a dendrogramme based on the measure of Jaccard distance to estimate the amphibian fauna composition among the different types of physiognomy sampled. We conducted the analysis and built the graphics using the Vegan package in R program (© The R Foudation; Oksanen et al., 2015).

Results

During our sampling period, we listed 27 species of amphibians distributed in five families (Fig. 2; Table 1). The richest family was Hylidae (n=12; 44.4% of the total number of species), followed by Leptodactylidae (n=11; 40.7%), Bufonidae (n=2; 7.4%), and Odontophrynidae and Strabomantidae, with one species each. Regarding the IUCN Red List, the species *Rhinella mirandaribeiroi*

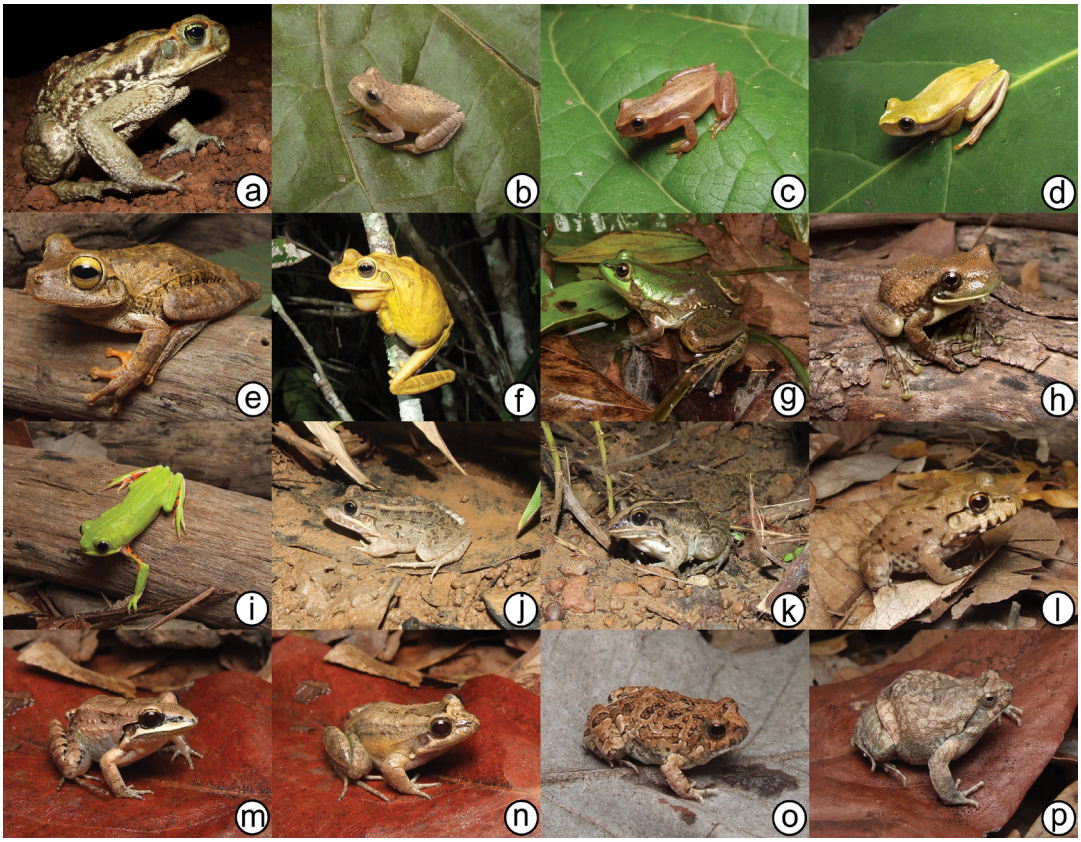

Figure 2. Some of the anuran species registered at Cerrado (savannah landscape) of Goiás State, Central Brazil. a) *Rhinella schneideri*, b) *Dendropsophus minutus*, c) *Dendropsophus nanus*, d) *Dendropsophus rubicundulus*, e) *Boana crepitans*, f) *Boana raniceps*, g) *Pseudis bolbodactyla*, h) *Trachycephalus typhonius*, i) *Pithecopus azureus*, j) *Leptodactylus chaquensis*, k) *Leptodactylus fuscus*, l) *Leptodactylus labyrinthicus*, m) *Leptodactylus mystaceus*, n) *Leptodactylus podicipinus*, o) *Physalaemus marmoratus* and p) *Physalaemus nattereri*.

Table 1. Anurans recorded in the Cerrado (savannah landscape), Goiás State, Central Brazil (period of sampling from 11 February to 20 February 2011), and physiognomies where they occur. RP = Rice Paddy; SV = Savannah; RF = Riparian Forest; DF = Dry Forest; GR = Grassland; FiR Forest in Regeneration; LOW = Lowland; PD = Pond/Dam; ANT = Anthropic Use Area.

Taxa	RP	SV	RF	DF	GR	FiR	LOW	PD	ANT
Bufonidae									
Rhinella mirandaribeiroi (Gallardo, 1965)	-	-	-	X	-	-	-	-	-
Rhinella schneideri (Werner, 1894)	X	X	X	-	X	X	X	X	X
Hylidae									
Dendropsophus minutus (Peters, 1872)	X	X	-	-	X	X	X	X	X
Dendropsophus nanus (Boulenger, 1889)	X	X	-	-	X	X	X	X	X
Dendropsophus rubicundulus (Reinhardt and Lütken, 1862)	X	X	-	-	X	X	X	X	X
Boana crepitans (Wied-Neuwied, 1824)	-	-	-	X	X	-	-	-	-
Boana raniceps Cope, 1862	X	X	X	-	-	X	X	X	X
Pithecopus azureus (Cope, 1862)	-	X	-	-	X	X	X	X	-
Pseudis bolbodactyla Lutz, 1925	X	-	-	-	-	X	X	X	-
Scinax fuscomarginatus (Lutz, 1925)	X	-	-	-	X	X	X	X	X
Scinax fuscovarius (Lutz, 1925)	X	-	-	-	X	X	-	X	X
Scinax x-signatus (Spix, 1824)	X	-	-	-	-	-	-	-	-
Scinax sp.	-	-	-	-	-	-	-	-	X
Trachycephalus typhonius (Linnaeus, 1758)	-	-	X	-	-	-	-	-	-
Odontophrynidae									
Proceratophrys goyana (Miranda-Ribeiro, 1937)	-	-	-	X	-	-	-	-	-
Leptodactylidae									
Leptodactylus chaquensis Cei, 1950	X	X	X	-	X	X	X	X	X
Leptodactylus fuscus (Schneider, 1799)	X	X	X	-	X	X	X	X	X
Leptodactylus labyrinthicus (Spix, 1824)	-	-	X	X	-	-	X	-	-
Leptodactylus mystaceus (Spix, 1824)	-	-	-	-	X	X	-	-	-
Leptodactylus podicipinus (Cope, 1862)	X	-	-	-	X	X	X	X	-
Physalaemus nattereri (Steindachner, 1863)	-	X	-	X	X	X	-	X	X
Physalaemus centralis Bokermann, 1962	-	X	-	-	-	X	-	-	-
Physalaemus cuvieri Fitzinger, 1826	X	-	-	X	X	X	X	X	X
Physalaemus marmoratus (Reinhardt and Lütken, 1862)	-	X	-	-	-	-	-	-	-
Pseudopaludicola giarettai Carvalho, 2012	-	-	-	-	X	X	-	X	-
Pseudopaludicola sp.	X	-	-	-	X	X	X	X	-
Strabomantidae									
Barycholos ternetzi Miranda-Ribeiro, 1937	-	-	X	-	-	-	-	-	-

and *Pithecopus azureus* are listed as Data Deficient (DD). The rarefaction curve (Fig. 3a) presents ascending format and large amplitude in the confidence intervals associated with last samples (i.e. sample points).

The similarity among the different sampled physiognomies (Fig. 3b) shows dry forest and areas of Riparian Forest with low similarity regarding other physiognomies, with an exclusive fauna (e.g. *Proceratophrys goyana, Leptodactylus mystaceus, Barycholos ternetzi, Leptodactylus labyrinthicus, Trachycephalus typhonius*) and does not have high β diversity (correlation coefficient = 0.9789). Combined with a low similarity among areas, in Cerrado *stricto sensu* occurred species exclusive to this environment (e.g. *Physalaemus marmoratus*). The specie-specific physiognomies are described in Table 1.

Another important aspect is the high β diversity index between lowlands and rice paddy (Fig. 4; correlation coefficient = 0.9663). Rice paddies are composed of wetlands and present some seasonal drought dynamics as well as lowlands area.

From the analysis of the special organization of species composition, we observed the formation of two gradients of heterogeneous breeding sites (NMDS, stress=0.1291; Fig. 3b): open formations represented by rice paddy, lowland fields, grassland, pond/dam, Cerrado *stricto sensu* and anthropic use areas; and forest formations, composed by dry forest areas and riparian forest. Species as *Dendropsophus minutus*, *Dendropsophus nanus*, *Dendropsophus rubicundulus*, *Boana raniceps*,

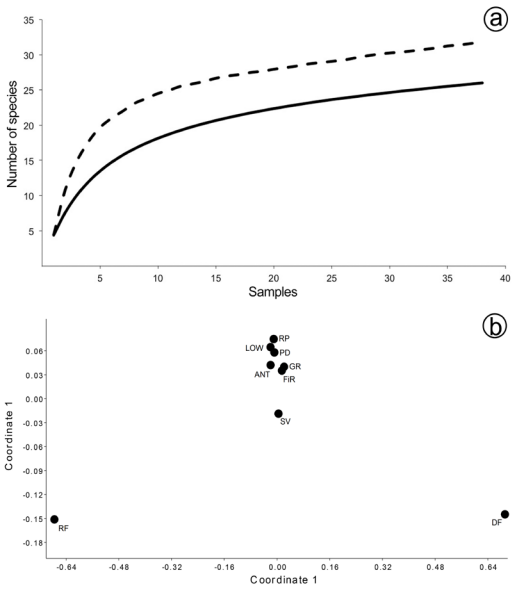

Figure 3. a) Accumulation curve for anurans sampled in the Cerrado (savannah landscape) study area. Black line represents the accumulation curves, dashed line represents species estimates based on Jacknife1; b) Similarity among different Cerrado (savannah landscape) physiognomies according to the anurans presence registered in the studied areas. *r* = Cophenetic Correlation Coefficient. Abbreviations of the physiognomies studied as in Table 1.

Scinax fuscomarginatus, *Scinax fuscovarius* and *Leptodactylus podicipinus* influenced the formation of the species group belonging to open environments, once we found these species predominantly in these environments. In the other hand, the presence of species *Rhinella mirandaribeiroi*, *Proceratophrys goyana*, *Boana crepitans*, *Trachycephalus typhonius*, *Barycholos ternetzi* and *Leptodactylus mystaceus* influenced the formation of the group of species recorded more often in the forested areas.

Discussion

We listed 27 species of amphibians, corresponding to 24% of the richness known to the Cerrado, which indicates high regional diversity and similar structure registered in other Cerrado areas nearby to the study area. For instance, Cintra et al. (2009) found 30 species of amphibians in an area about 90 km from our study area and Moreira et al. (2009) found 25 species of amphibians from termite mounds about 160 km our sampling area. We recorded two species listed on IUCN Red List as Data Deficient (DD) (*Rhinella mirandaribeiroi* and *Pithecopus azureus*). Moreover, we recorded three endemic species from Cerrado (*Proceratophrys goyana*, *Barycholos ternetzi* and *Physalaemus nattereri*). Hylidae was the most representative family in our survey. Our results were expected, because this taxon contains the greatest diversity on national scale (Segalla et al., 2014), as well as in the Brazilian Cerrado (Colli et al., 2002).

The anurofauna that we recorded did not differ from amphibian fauna found in other Brazilian savannahs' areas, probably due to the similar environmental characteristics, such as the same vegetation types (Cintra et al., 2009; Moreira et al., 2009). Soil features may also be relevant to this aspect, because the clay percentage and drainage rate might influence the abundance of some anuran species (Woinarski et al., 1999; Watling, 2005; Menin et al., 2007). Some Cerrado species presents explosive breeding behaviour (Wells, 1977), and we observed species with such pattern as *Trachycephalus typhonius*, *Physalaemus nattereri* and *Proceratophrys goyana*. Although the rarefaction curve tends to stabilize, it shows that increasing the sampling effort, new species may be found in the area. Besides that, the

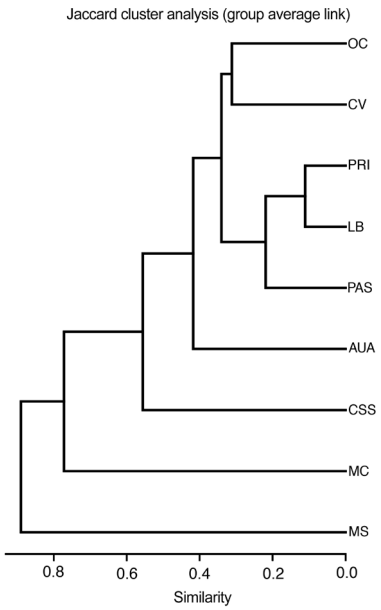

Figure 4. Relationship between the two axes generated after NMDS ordination, summarizing 38 Cerrado (savannah landscape) sampled areas registered at Goiás State, Central Brazil.

accumulation curves rarely fully stabilize, especially in tropical ecosystems, rich in rare species (Santos, 2003). Thus, the number of species we registered does not reflect the total richness of the area.

We listed two species difficult to identify due taxonomic problems. The first one, belonging to the *Pseudopaludicola* genus, lacks a broad review to understand the distribution patterns of this group, which probably will result the description of new species. Recently, acoustic traits have showed a very important tool for identify *Pseudopaludicola* species (Carvalho and Giaretta, 2013; Magalhães et al., 2014; Pansonato et al., 2014). However, we did not record the vocalization of *Pseudopaludicola* sp. Nevertheless, we could assign one of the collected specimens as *P. giarettai*, due to some recorded individuals, which have been recently identified in the region (Carvalho et al., 2015). To identify the specimens of *Scinax* sp. we need more specimens to conduct a comparative study of morphology and vocalization, since there are great variability and overlap of characters considered as diagnoses for this genus.

The study sites presented two mainly characteristics directly related to the similarity of the physiognomies: one formed by forested areas (dry forest and riparian forest) and the other composed by open areas (paddy rice, lowlands, pounds/dam, grasslands, anthropic use areas, regeneration forest and savannah). This division may be explained by the similarity of some structural features among the physiognomies that compose each area (for example, dry forest and riparian forest present the same floristics features; Ribeiro and Walter, 1998). The spacial segregation was influenced by the recording of species with generalist habits (Bertolluci and Rodrigues, 2002; Moraes et al., 2007; Oda et al., 2009), which do not depend on forested habits for reproduction. Thus, species that we recorded such as *Rhinella schneideri*, *Boana raniceps*, *Leptodactylus chaquensis* and *Leptodactylus fuscus* can be considered generalists, because they were found in almost all sampled areas. We registered *Trachycephalus typhonius* and *Barycholos ternetzi* exclusively in riparian forest environments. *Proceratophrys goyana* is a terrestrial frog, but depends on pools and ponds for breeding (Colli et al., 2004), and we recorded this species in the dry forest. Previous works of Cerrado herpetofauna distribution, as well as our work, recorded low spatial overlap among species from open and forest areas (Brasileiro et al., 2005; Nogueira et al., 2005; Gambale et al., 2014).

A factor favouring the anuran persistence in areas with anthropogenic changes is the presence of sites for breeding (Henderson and Powell, 2001; Lion et al., 2014). This seem the case of some species from the family Hylidae (e.g. *Dendropsophus* spp., *Boana*, *Pseudis*) and Leptodactylidae (e.g. *Pseudopaludicola*), which were recorded mainly in open areas and have no specialized breeding mode (mode 1; Haddad and Prado, 2005). Most of species of these families used the paddy rice as complementary habits (see Table 1), both as breeding site and to moving for other habitats. Since rice paddies are commonly drastically altered environments, the presence of Hylidae species corroborates the opportunistic habit of Hylidae species and that they are highly resilient to structural habitat changes (e.g. Machado and Maltchik, 2010; Piatti et al., 2010).

Our results show that different types of vegetation (e.g. forested and opened areas) contribute to the diversity of anurans in a savannah landscape, reinforcing that tropical open areas also are important for maintaining biodiversity in the Cerrado (Colli et al., 2002; Nogueira et al., 2009). The record of endemic species or listed as Data Deficient (DD) bring the basic data for future opportunities of study for the region, aimed at conservation and management strategies for these areas that are often neglected in studies to maintaining biodiversity or legal protection (Diniz-Filho et al., 2007). The lack of protection plans for these areas can lead to population decline or even local extinction of these species, since the habitats are subjected to anthropic activities and drastic disturbances.

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