ORNITOLOGÍA NEOTROPICAL
(2018) 29: 281–288

ORIGINAL ARTICLE

Sociedad de Ornitología Neotropical

OWL ASSEMBLAGES IN FRAGMENTS OF ATLANTIC FOREST IN BRAZIL

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Abstract · Habitat loss and fragmentation is recognized as one of the main causes of global biodiversity declines. Birds of prey are considered good environmental bioindicators because they are sensitive to changes in the environment and can suffer local extinctions due to habitat fragmentation. In this study, we aimed to determine whether forest fragment area is correlated with the richness and abundance of owl species, and whether owl species recorded exhibit preferences for fragment edge or interior. The study was undertaken in six remnants of southeastern Atlantic Forest located in Minas Gerais State, Brazil. Six species of owls were recorded: Buff-fronted Owl (*Aegolius harrisii*), Tropical Screech-Owl (*Megascops choliba*), Tawny-browed Owl (*Pulsatrix koeniswaldiana*), Striped Owl (*Asio clamator*), Mottled Owl (*Strix virgata*), and Rusty-barred Owl (*Strix hylophila*). *Megascops choliba* was the most abundant species. The richness and abundance of species were higher at the edge when compared to the interior of the fragments. The owl species recorded did not seem to prefer the forest interior, while *M. choliba* had a preference for forest edges. This study adds new empirical knowledge on the effects of fragmentation on Neotropical owl communities.

Resumen · Comunidades de lechuzas y búhos en fragmentos de bosque Atlántico en Brasil
El proceso de pérdida y fragmentación del hábitat se identifica como una de las principales causas del declive de la biodiversidad mundial. Las aves de presa se consideran un buen bioindicador ambiental porque son sensibles a los cambios en el medio ambiente y pueden extinguirse localmente con la fragmentación del bosque. El objetivo del estudio fue responder a las siguientes preguntas: ¿La fragmentación de los bosques influyen en la riqueza y abundancia de las especies de búhos? ¿Las especies de búho tienen preferencia por el borde o el interior de los fragmentos del bosque? El estudio se llevó a cabo de octubre de 2011 a septiembre de 2012 en seis localidades de la Mata Atlántica suroriental, ubicadas en el estado de Minas Gerais, Brasil. Seis especies de búhos fueron registradas: Lechucita Acanelada (*Aegolius harrisii*), Currucutú Común (*Megascops choliba*), Lechuzón Mocho Chico (*Pulsatrix koeniswaldiana*), Búho Gritón (*Asio clamator*), Mocho Carijó (*Strix virgata*) y Rusty-barred Owl (*Strix hylophila*). *M. choliba* fue la especie más abundante. La riqueza y abundancia de especies fue mayor en el borde comparado con el interior de los fragmentos. La comunidad de búhos en nuestra área de estudio no parece tener preferencia por el interior del bosque, sin embargo, *M. choliba* es más abundante en los bordes del bosque. Este estudio aporta nuevos conocimientos sobre la riqueza y abundancia de los búhos neotropicales y su respuesta a la fragmentación de la Mata Atlántica.

Key words: Community composition · Habitat use · Species richness · Strigiformes · *Aegolius harrisii* · *Asio clamator* · *Megascops choliba* · *Pulsatrix koeniswaldiana* · *Strix hylophila* · *Strix virgata*

INTRODUCTION

The Atlantic forest is classified as a biodiversity hotspot (biomes with high threat level, a high number of species and with a high degree of endemism) (Myers et al. 2000). The main causes for the loss of area and the fragmentation of the Atlantic Forest are agricultural activities, pastures, mining, and other human occupations (Myers et al. 2000, MMA 2003). In this context, habitat change is identified as one of the main causes for the decline of the world's biodiversity (Fischer & Lindenmayer 2007, Sodhi 2009) including species of nocturnal birds, like the Strigiformes (Walter et al. 2017).

An already well-known process of forest fragmentation with serious consequences for fauna and flora is the edge effect (Murcia 1995, Myers et al. 2000). The edge effect causes the loss of structural features (e.g., canopy cover, diameter of trees) of forests, which could affect animal assemblages (Murcia 1995, Gimenes & dos Anjos 2003). In this respect, top predators seem to be more vulnerable to fragmentation than other trophic guilds (Melo et al. 2016). First, top vertebrate predators are usually large and tend to require more resources such as area and food, consequently, are more likely to be affected by habitat

Receipt 6 November 2017 · First decision 8 January 2018 · Acceptance 22 October 2018 · Online publication TBA

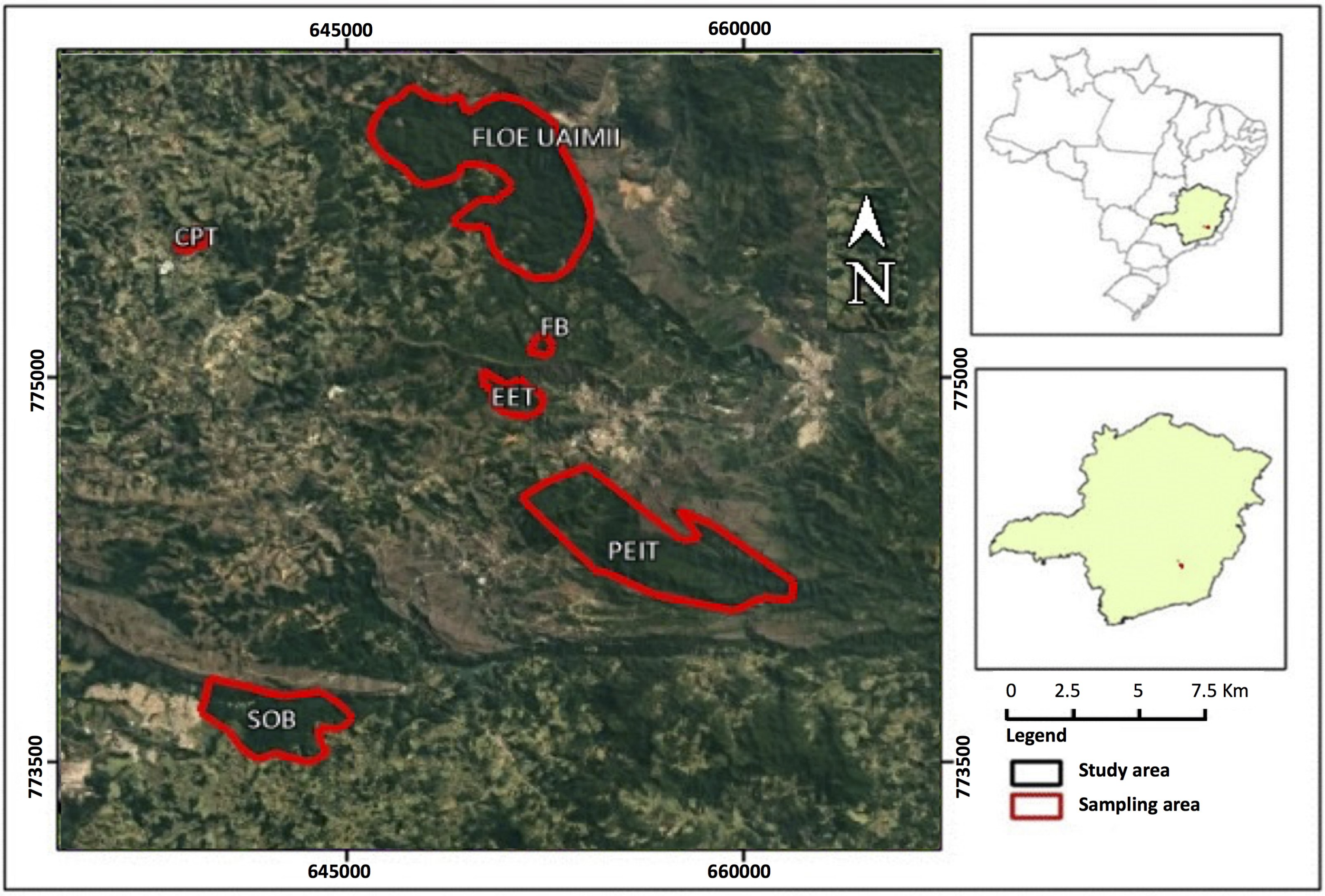

Figure 1. Map of the study area indicating forest fragments sampled for owls in Minas Gerais, Brazil. Names of fragments as in Table 1.

loss. Second, large predators occur in low densities and have more vulnerable population dynamics (Henle et al. 2004). For large owls, the edge effect can, for example, reduce the availability of habitat for nesting, hunting, and other activities (Walter et al. 2017). Loss, fragmentation and degradation of natural habitats are the probable main causes for the reduction and extinction of populations of top predators in Brazil (IBAMA 2008).

The biology of nocturnal birds is relatively poorly known, especially regarding habitat use and selection (Zuberogoita & Campos 1998, Amaral 2007). The biology of most Neotropical owls is particularly poorly understood despite recent studies (Enríquez-Rocha & Rangel-Salazer 2001, Motta-Junior 2006, Esclarski & Cintra 2014). Nonetheless, some studies have found relationships between the occurrence of owls and characteristics of vegetation structure (Bart & Forslnan 1992, Barros & Cintra 2009, Menq & dos Anjos 2015). Owls are known to choose more favorable habitat in terms of the availability of resources such as food and nest sites, and physiological stress this is weather (Solis & Gutiérrez 1990).
Some ecological studies with owls in Brazilian forests have dealt with issues related to forest structure and habitat selection in Amazonian (Borges et al. 2004, Barros & Cintra 2009, Esclarski & Cintra 2014) and Atlantic (Amaral 2007) forests. For large owls, habitat disturbance can, for example, reduce the availability of habitat for nesting, hunting, and other activities (Ward et al. 1998, Esclarski & Cintra 2014). Another important aspect of bird natural history is species-habitat association. Although Neotropical birds are associated with a variety of habitats in the Atlantic Forest (Zorzin et al. 2009, Kanegae et al. 2012) and savannas (Manica et al. 2010), few studies have focused on the habitat preferences of forest owls (del Hoyo et al. 1999, Motta-Junior & Braga 2012).

According to Motta-Junior & Braga (2012), studies on the basic requirements of Neotropical owls are scarce, and in Brazil studies on habitat use, population density, and reproductive biology are non-existent. In this study, we aimed to determine whether forest fragment area is correlated with the richness and abundance of owl species, and whether owl species recorded exhibit preferences for fragment edge or interior.

MATERIALS AND METHODS

Study area. The study was conducted from October 2011 to September 2012 in six forest fragments located in natural protected areas, covering a total of 12 ha (Figure 1 and Table 1), in the municipality of Ouro Preto, state of Minas Gerais, Brazil. The fragments of forest are classified as semi-deciduous Atlantic Forest (Bhakti et al. 2018). The interior of the fragments present rich plant species communities, with tree heights reaching more than 20 m. In contrast, forest edges have a lower diversity of trees and vegetation structure, with tree heights averaging 5–15 m, high light intensity, and abundant lianas (Bhakti et al. 2018).

Sampling design and data collection. To determine the richness and abundance of species of owls we used linear transects and audio playbacks of vocalizations, following Bibby et

Table 1. Owl species richness and abundance in six forest fragments in Minas Gerais, Brazil: Floresta Estadual do Uaimii (FLOE UAIMII), Parque Estadual do Itacolomi (PEIT), Parque Estadual da Serra do Ouro Branco (SOB), Estação Ecológica do Tripuí (EET), Fazenda da Brígida (FB), and Condomínio Paragem do Tripuí (CPT).

Fragment	Coordinates	Area (ha)	Richness	Abundance
FLOE UAMMI	20°15'34.87''S, 43°35'20.71''W	3248	1	1
PEIT	20°26'53.22"S, 43°29'45.91"W	3244	4	12
SOB	20°31'29.14"S, 43°39'01.94"W	321	2	4
EET	20°22'52.51"S, 43°32'43.78"W	304	3	9
FB	20°21'25.86"S, 43°32'08.36"W	133	3	4
CPT	20°18'47.60''S, 43°41'03.56''W	111	1	2

Table 2. Owl species recorded in six forest fragments in Minas Gerais, Brazil, with information on sampling method (transect or playback) and degree of sensitivity (DS, based on Stotz *et al.* (1996) in each forest fragment. Abbreviations for studied forest fragments are as in Table 1. Number of records = abundance.

Species	Sampling method		DS	Fragment of forest						
	Transect	Playback		FB	CPT	SOB	EET	FLOE UAIMII	PEIT	Total
Aegolius harrisii	2	1	High	1	0	0	1	0	1	3
Megaschops choliba	13	9	Low	3	2	2	7	0	8	22
Pulsatrix koeniswaldiana	0	1	High	0	0	0	0	1	0	1
Asio clamator	1	0	Low	0	0	0	0	0	1	1
Strix hylophila	3	0	High	0	0	0	1	0	2	3
Strix virgata	2	0	Average	0	0	2	0	0	0	2

al. (1998), during a total of 47 field trips. Linear transect (Condomínio Paragem do Tripui - CPT – n = 9; Estação Ecológica do Tripuí - EET – n = 6; Fazenda da Brígida - FB – n = 8, Floresta Estadual do UAMII -FLOEUAIMII – n = 9, Parque Estadual do Itacolomi - PEIT – n = 8, and Parque Estadual da Serra de Ouro Branco - SOB – n = 7) sampling began at the edge of forest fragments and moved towards their interior for 1 km. Censuses involved walking slowly (1.5 km/h), and making visual or auditive detections (Bibby et al. 1998). Censuses began after sunset (18:00 h) and finished around 21:00 h.

Audio playback. After finishing walking the transects, audio playbacks were performed at three fixed points separated by 500 m along the transects. At each of the three points, we listened for two minutes prior to beginning a playback session of the owl species expected to occur in the area. Playback order went from smallest to largest: Buff-fronted Owl (*Aegolius harrisii*), Ferruginous Pygmy-Owl (*Glaucidium brasilianum*), Tropical Screech-Owl (*Megascops choliba*), Tawny-browed Owl (*Pulsatrix koeniswaldiana*), Striped Owl (*Asio clamator*), Mottled Owl (*Strix virgata*), and Rusty-barred Owl (*Strix hylophila*) (Borges et al. 2004). A Sony TCM-5000 recorder with an external amplifier was used for playbacks. The sound reproductions consisted of playing vocalizations of each species (recordings obtained from xeno-canto; www.xeno-canto.org). The accession codes for each species recording are: *Aegolius harrisii* - XC20899; *Glaucidium brasilianum* - XC142220; *Megascops choliba* - XC108640; *Pulsatrix koeniswaldiana* - XC18770; *Asio clamator* - XC15031; *Strix virgata* XC351036; *Strix hylophila* - XC266601. Playbacks lasted 2 min for each species, with an interval of 3 min between species to listen for responses. The sequence of the playbacks from smaller to larger species was used to avoid inhibiting the response of smaller owls by the playback of larger owls. Once an owl was detected, the playback was immediately stopped to prevent the bird moving away from its original perch, following Borges et al. (2004). Playback sampling started at 21:30 h and lasted 2 h, with an average of 15 min at each sampling point.

Owls were rarely seen, and their positions were estimated by approximation based on individual vocalizations (Zuberogoitia & Campos 1998). The data collected included the species, the position of the individual at the edge or in the interior of forest, and the type of record (visual or auditory). We considered the forest border to extend 100 m into the forest from the edge of the fragment (Nascimento & Laurance 2006).

Data analysis. Species richness was estimated using Estimates 8.2.0 (Colwell & Coddington 1994) and expected species richness was calculated using the Chao estimator of first and second order (Chao 1 and Chao 2) (Magurran 1988). We combined (added) records from transects and playbacks to obtain richness and abundance. The units for abundance are number of records. Species richness and abundance were compared through General Linear Model analysis (GLM) using software R version 3.1.0 (R Development Core Team 2014) and the following models: First GLM: richness and abundance of owls as response variable and size and fragment as explanatory (Poisson error distribution); Second GLM: richness and abundance of owls as response variable

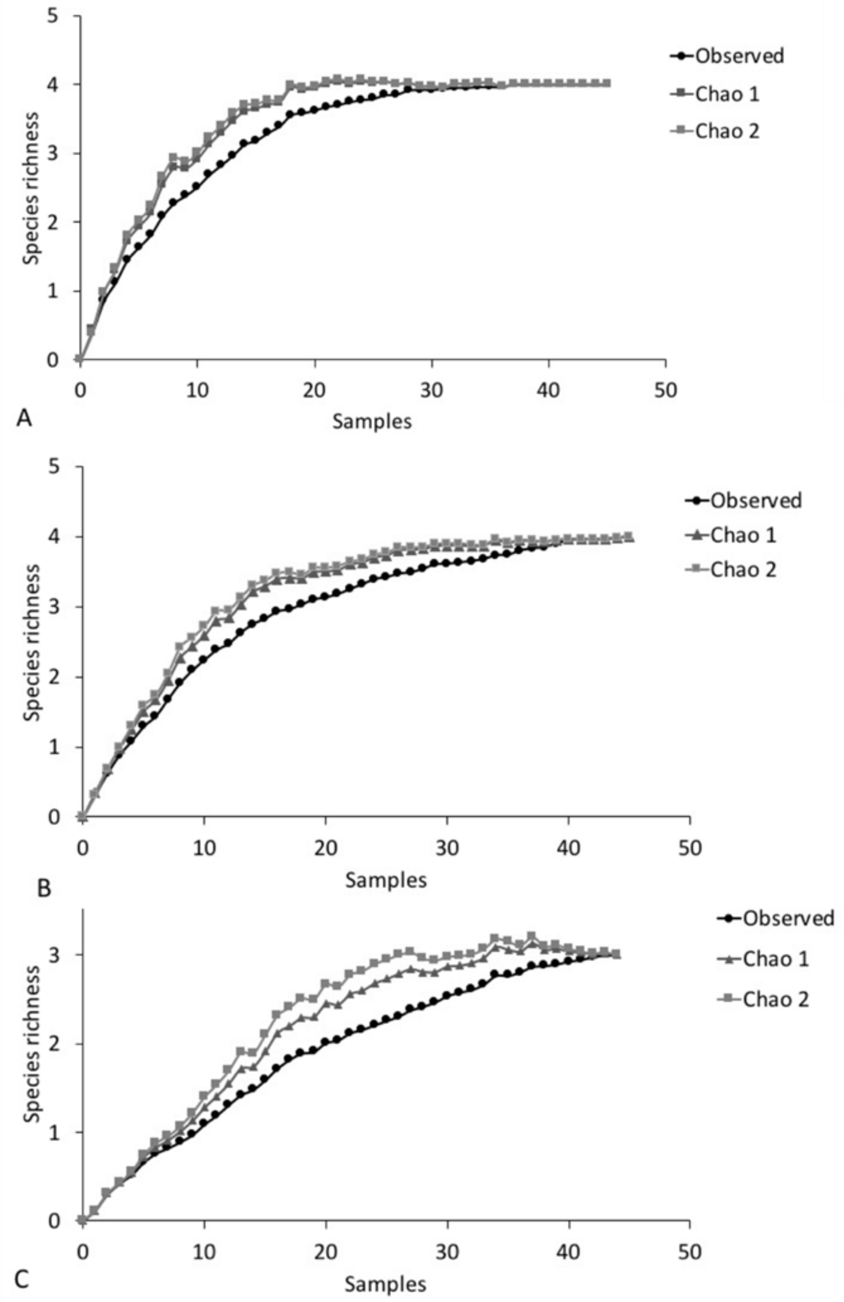

Figure 2. Sample based rarefaction curves, for owl species richness in: A- all sampled fragments, B-Edge of fragments and C-Interior of fragments. Chao 1- observed value for owl richness based on abundance, Chao 2: observed value for owl richness based on presence-absence.

and habitat as explanatory (edge_interior, normal error distribution).

Analysis of the use of edge and interior habitats was performed through GLM using only data from the censuses carried out on the linear transects that is, excluding the playback. Only these data were used because they included the exact locations of the habitat used by owls, whereas the playback method can lure owls away from their original location. The species recorded were classified according to their degree of sensitivity to habitat modifications (low, average, or high sensitivity) following the classification proposed by Stotz et al. (1996).

RESULTS

We recorded six owl species (Table 2) using the two methods. Of the 32 records, 22 (66.7%) were of *M. choliba*, while the remaining species had one to three records each (Table 2). *Megascops choliba* was the most common species, occurring in five of the six fragments, while *A. clamator*, *S. virgata,* and *P. koeniswaldiana* were the least common, each being recorded from a single fragment (Table 2). The total observed species richness and the richness in each habitat (edge and interior) were very close to the expected (Figure 2 A–C, respectively). Species richness was not significantly related to fragment size ($F_{1,46}$ = 48.896; P > 0.533), and did not differ among fragments ($F_{5,41}$ = 19.026; P > 0.093). Species abundance was not significantly related to fragment size ($F_{1,41}$ = 41.773; P > 0.931), but was different among fragments ($F_{5,41}$ = 41.773; P < 0.012) (Figure 3). Species richness ($F_{1,92}$ = 30.851; P < 0.008) and abundance ($F_{1,92}$ = 30.851; P < 0.008) of owls were higher for edge compared to forest interior (Figure 4). At the species level, abundance of *M. choliba* was higher in edge compared to interior ($F_{5,41}$ = 16.213; P <

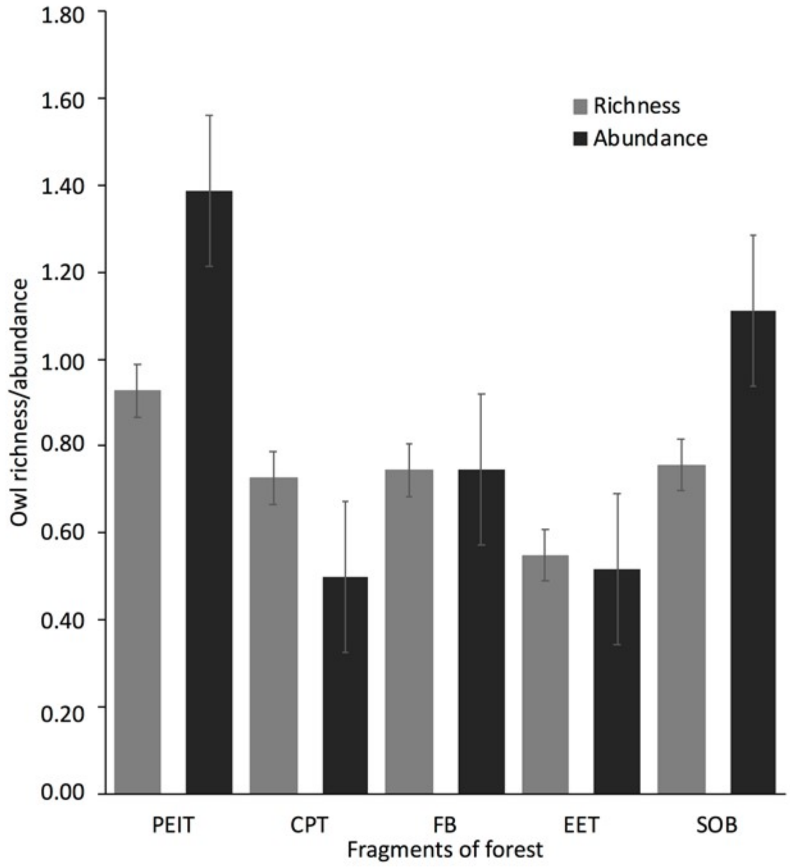

Figure 3. Mean ± standard deviation of owl abundance in the six studied forest fragments, Minas Gerais, Brazil. Parque Estadual do Itacolomi (PEIT), Condomínio Paragem do Tripuí (CPT), Fazenda da Brígida (FB), Estação Ecologica do Tripuí (EET), and Parque Estadual da Serra do Ouro Branco (SOB).

0.027) (Table 3); no formal comparisons in abundance between edge and interior were performed for the other species due to low sample sizes: *S. hylophila* (n = 4), *A. harrisii* (n = 3), *S. virgata* (n = 2), *P. koeniswaldiana* (n = 1), and *A. clamator* (n = 1).

DISCUSSION

Owl richness of the study region was similar to that found at other Atlantic Forest localities (Amaral 2007, Fink et al. 2012). It was also similar to the six species reported by Borges et al. (2004) and the eight species reported by Lloyd (2003), both from the Amazonian Forest and using the same methods as the present study. This finding indicates that the methods applied were efficient to detect the owl species present in the studied areas (Lloyd 2003, Hausleitner 2006, Amaral 2007).

Forest-fragment size was not a good predictor of owl richness and abundance. The presence of *A. harrisii*, a species with high degree of sensitivity to habitat disturbance (see Parker et al. 1996), in small fragments (EET and FB) can be explained by connectivity among studied habitats that reduce the area effect of fragmentation (Bhakti et al. 2018). It should also be considered that owl species have high dispersal abilities in matrices and differences in their habitat preferences. For instance, in our study, most owl species recorded in fragments (e.g., *M. choliba*, *A. clamator*, and *S. virgata*) occur primarily in degraded habitats adjacent to forest fragments, but also in the latter. These species are completely independent of, or respond positively to, forest loss and fragmentation *per se* (Melo et al. 2016).

It should be emphasized that habitat features like heterogeneity, prey density, and nesting site are important to owls when selecting habitats (Ward et al. 1998, Esclarski & Cintra 2014). We found the highest abundance of owls at both EET, which is a small fragment, and PEIT, a large fragment, a result driven mainly by the high abundance of *M. choliba*, a species with a low degree of sensitivity (Menq & Anjos 2015).

Owl-species richness and abundance were higher at edges than in the interior of the fragments, with *A. harrisii, M. choliba, S. virgata,* and *S. hylophila* being recorded in both habitats, although some of those species are more sensitive to habitat change due to fragmentation, e.g., *A. harrisii* and *S. hylophila* (Stotz et al. (1996). Edge effects can be both positive and negative, causing some species to thrive and others to perish. For example, the microclimatic regime of the ecotone, plus the proximity of resources from two different habitat types, can support a diverse range of species (Gimenes & Anjos 2003, Terraube et al. 2016). Some "edge species," e.g., generalistic owls such as *M. choliba,* tend to flourish in the edge environments between forests and clearcuts where, on the opposite, *S. hylophila* tends to suffer. According to Murcia (1995), tree mortality increases along edges, which provides nesting sites for owls, and the density of dead trees has been found to be related to the richness of owl species that nest in dead wood (Boyle et al. 2008, Pereira et al. 2009, Pereira et al. 2015). According to Aguiar & Naiff (2009), species of owls that prefer edges benefit from the fragmentation of forests and have even be recorded in more open landscapes such as in cerrado and caatinga. In the Atlantic Forest, some species of owls will use fragments as small as 400 x 30 m as nesting sites (Aguiar & Naiff 2009). Kanegae et

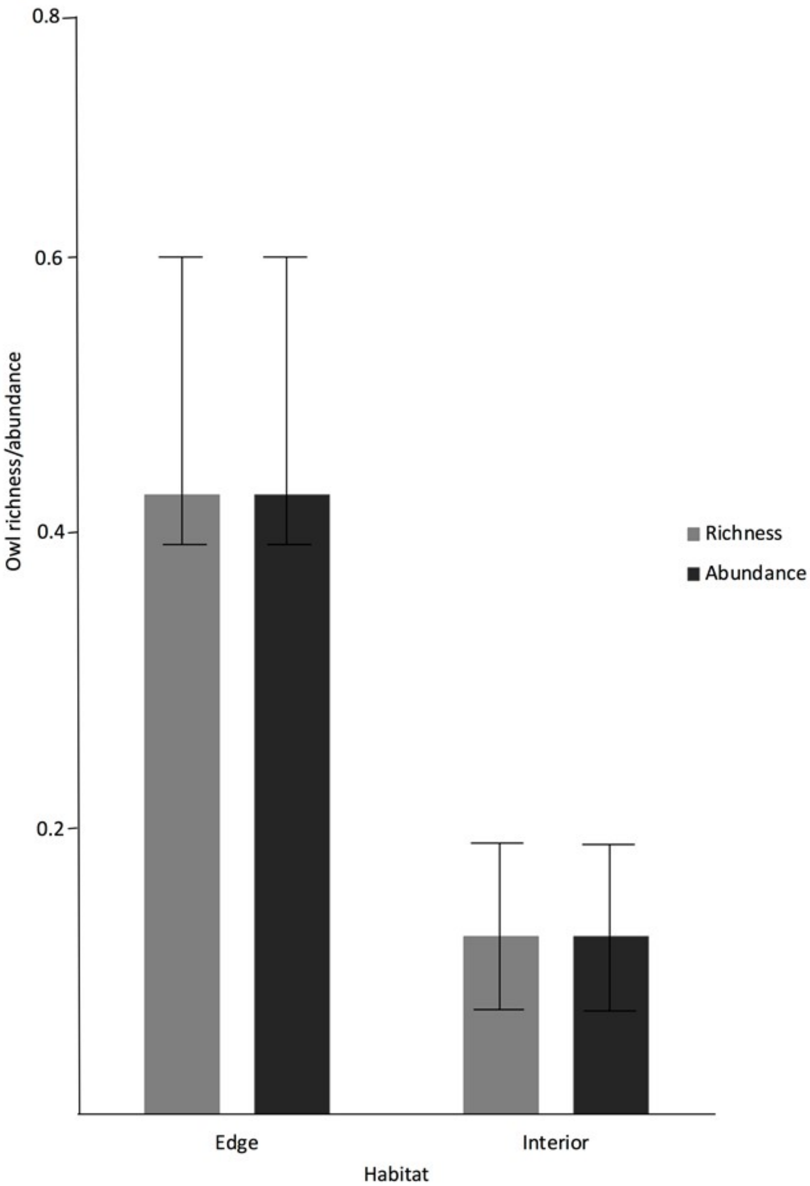

Figure 4. The mean ± standard deviation of owl richness and total abundance (number of records) in the studied forest fragments at Ouro Preto, Minas Gerais, Brazil, comparing edge and forest interior sites.

Table 3. Abundance of owl species in two habitats (edge and interior) of six forest fragments in Minas Gerais, Brazil: Floresta Estadual do Uaimii (FLOE UAIMII), Parque Estadual do Itacolomi (PEIT), Parque Estadual da Serra do Ouro Branco (SOB), Estação Ecológica do Tripuí (EET), Fazenda da Brígida (FB) and Condomínio Paragem do Tripuí (CPT). *Aegolius harrisii* and *P. koeniswaldiana* were sampled only with playback.

Owl species	Edge	Interior
Asio clamator	1	0
Aegolius harrisi	2	1
Megaschops choliba	11	2
Pulsatrix koeniswaldiana	0	1
Strix hylophila	2	0
Strix virgata	2	0

al. (2012) found no relationship between the presence of *P. koeniswaldiana* and forest-fragment size, but these authors emphasized the importance of fragments of different sizes for the species since they serve as "stepping-stones" and nesting areas.

The negative effects of habitat fragmentation on biodiversity are well documented in the literature, and may lead to local extinctions in the remaining fragments of Atlantic Forest (Nally et al. 2000, Fahrig 2003, Ribeiro et al. 2009). Differing from what was expected, in the present study we found a similar number of species in all fragments, even between forest interior and edges. On the other hand, the number of individuals recorded was different among fragments. The lack of a fragmentation effect could be explained by the fact that the size of studied fragments was above the "threshold" of fragment-size tolerance by forest owls at the scale that we sampled.

ACKNOWLEDGMENTS

We wish to acknowledge Universidade Federal de Ouro Preto - MG (Programa de Pós Graduação em Ecologia de Biomas Tropicais) for granting a scholarship to RMC and CNPq for granting a scholarship to YA. We thank Instituto Estadual de Florestas de Minas Gerais and the staff of Condomínio Tripui for the permitting field work at the state parks. We are grateful to all people who were involved in the project since its conception, including assistance in field work, and to two anonymous reviewers for helping to improve the manuscript.

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