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Bird Fauna Composition in a Protected Area in Southern Brazil

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The integrity of natural landscapes is affected by human actions, mainly by the intensification and expansion of agriculture. Factors such as fragment size and the structure of the environment can determine changes in the structure and composition of bird assemblages. In this study we evaluated the bird species composition in three structurally different forest environments, defined as the Core areas, Edge areas, and Buffer areas. The surveys were performed in the Natural Park of Sertão (NPS) and its surroundings in the southern limit of the Atlantic Forest, southern Brazil. To record species composition of birds, the point count method was used. The bird species were categorized according to feeding habits, habitat use, and sensitivity to forest fragmentation. A total of 131 species of birds distributed in 18 orders and 38 families were recorded. The species composition varied between the three areas and there was a significant difference in diversity between the Core and Edge areas and the Core and Buffer areas. Omnivorous species were found more in the Buffer areas than in the Core areas. Species that use the Broad habitat were more frequent in the Buffer and Edge areas than in the Core areas. Species that use the Forest habitat were found more in the Core areas than in the Buffer areas. Most recorded species (66%) have low sensitivity to forest fragmentation. The assemblage patterns found in this study, notably the differences among the three areas in diversity and species composition, can be explained by the ecological traits and the sensitivity levels of birds to forest fragmentation, which in turn seem to reflect different forest structures in the NPS and its surroundings. Although the Edge and Buffer areas have greater diversity, the Core areas showed great importance in maintaining species that are more sensitive to forest fragmentation. Even the largest fragments (such as the NPS), considering the regional context, may have bird species that are widely distributed and less sensitive to forest fragmentation. Forested habitat species may no longer occur or be restricted to the core area of the fragments. For conservation of bird fauna in the NPS, the maintenance of the core areas is essential, especially for those species that require a structurally preserved environment.

Key words: Forest fragmentation, Edge effect, Bird conservation, Community ecology, Agricultural matrix

BACKGROUND

Forest degradation and fragmentation processes are widely distributed in the world and are especially associated with the expansion of human development frontiers (Haddad et al. 2015; Pendrill et al. 2022). The integrity of natural landscapes is affected by human actions, mainly by the intensification and expansion of agriculture (Solórzano et al. 2021). These changes in land use and cover can reduce the quantity and quality of natural habitats (Hill and Curran 2003). Therefore, the degradation of natural landscapes promotes changes in biodiversity, ecosystem stability, and resilience in the face of disturbances (Fahrig 2003).

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Decreasing area and increasing fragmentation reduce species richness (Ibáñez et al. 2014; Haddad et al. 2015) and the diversity of functional characteristics of biological communities (Bregman et al. 2016; Luz et al. 2019). For example, forest fragmentation increases the edge effect and, consequently, the number of generalist species in forest fragments (Menke et al. 2012). In extreme situations, in small patches, local extinction of certain groups of species may occur, such as those restricted to conserved forest habitats (Devictor et al. 2008).

Forest fragmentation promotes changes in landscapes that may reflect on the structure and composition of bird assemblages (Anjos and Boçon 1999; Silva et al. 2017). Factors such as fragment size and structure of the environment can determine the presence or absence of species (Fischer and Lindenmayer 2007). Larger size and circular shape, with less edge effect, contribute to a larger central area of the fragment with a higher degree of conservation (Laurance et al. 2002).

The structure of the environment also influences the diversity of birds in a region (Anjos et al. 2019). The degree of tolerance of each species to changes in its environment varies according to its ability to adjust to habitat conditions (Silva et al. 2017; Mikolaiczik et al. 2019). Thus, different areas of a fragmented forest may have differences in species composition, depending on the degree of alteration generated by the effect of the matrix habitat. The maintenance of connectivity is associated with the physical arrangement of the landscape and the permeability of the matrix, that is, the ability of the species to overcome the matrix habitat and to move between the fragments (Metzger and Décamps 1997; Tischendorf and Fahrig 2000). In this way, the maintenance of populations of bird species in fragmented environments depends on the relationship between the quality and structure of the forest fragment with the size and isolation of the fragment (Boscolo and Metzger 2011).

In order to understand the mechanisms that influence the dynamics of species, in addition to the structural factors of the fragments and the matrix, it is also necessary to consider the traits of the species (Uezu and Metzger 2011). The greater the structural and microclimatic differences, the lower the probability of species sensitive to fragmentation being able to use matrix or fragment edges (Stouffer et al. 2006). The effects of forest fragmentation and environmental structure on bird assemblages also show regional variations, which probably reflects the complex relationship between habitat modification and the characteristics of each region (Restrepo et al. 1997; Silva et al. 2017; Anjos et al. 2019; Mikolaiczik et al. 2019).

The Atlantic Forest is one of the most biodiverse biomes in the world; however, it is also one of the most threatened (Ribeiro et al. 2009; Marques et al. 2021). The remaining area of this biome with natural forest cover corresponds to only 13.1% of that of the original forest (Fundação SOS Mata Atlântica, INPE 2019). The forest cover is mainly distributed in small and isolated fragments, composed of forests of various ages and in different stages of regeneration (Lira et al. 2021), incorporated into a matrix of degraded areas, pastures, agricultural and urban areas (Joly et al. 2014).

The Natural Park of Sertão (NPS) is a protected area located at the southern limit of the Atlantic Forest distribution (Slaviero 2014). During the 1960s, the region where the NPS is located, while originally covered by forest, became highly fragmented by nearby logging and agricultural expansion. The advance of agricultural cultivation in the region, with an emphasis on soybean, corn, and wheat crops, increased human pressure in the areas surrounding the Park (Slaviero et al. 2014).

Understanding how the forest structure influences the bird assemblages, mainly in highly fragmented regions inserted in an agricultural matrix, is essential for the conservation of birds, especially in the Atlantic Forest, with its high endemism and high anthropogenic pressure (Barbosa et al. 2017). In this study, we evaluated the avifauna assemblage patterns in the NPS and its surroundings in order to answer the following questions: How does the bird species composition vary between different forest structures in the NPS? Are the patterns found associated with the ecological traits of the species and their sensitivity to forest fragmentation?

MATERIALS AND METHODS

Study area

The study was carried out in the Natural Park of Sertão (NPS) and its surroundings, located in the municipality of Sertão, in the north of Rio Grande do Sul state, Brazil (Fig. 1). The area has slightly undulating relief, with an approximate altitude of 650 m (SERTÃO 2015). The climate has an average annual temperature of 17.5°C and an average annual rainfall of 1,800 mm, with well-distributed rainfall throughout the year. Originally covered by the Atlantic Forest biome, the landscape of the study area is characterized by the predominance of Mixed Ombrophilous Forest (Oliveira-Filho et al. 2015). The NPS consists of two forest fragments totaling 590.80 ha (Slaviero 2014). The study was performed in the largest fragment (513 ha) and in the forest remnants in its surroundings.

The surroundings of the NPS are characterized by the predominance of rural properties with an agricultural economy (SERTÃO 2015), in which small forest fragments occur, which may or may not be connected to the NPS (Fig. 1).

Bird surveys

The surveys were performed in structurally different forest environments, defined as the Core area, Edge area, and Buffer area of the NPS. The areas differ structurally, mainly in the height, volume, and average diameter of the trees, in addition to the richness of plant species and the stage of regeneration, which are influenced by the edge-core gradient (Slaviero et al. 2014).

The core areas of the NPS have higher vegetation, dense canopy, and older trees. In these areas, the advanced regeneration stage predominates, representing the most preserved sites of the NPS (Slaviero et al. 2014; SERTÃO 2015).

The edge areas in the NPS represented the transition between forest vegetation and the agricultural matrix (Slaviero et al. 2014). These areas are characterized by the intermediate stage of regeneration close to the agricultural matrix, and the advanced stage when closer to the core area of the fragment. In the NPS, the edge effect on forest vegetation is estimated at up to 250 meters, and the edge areas show greater plant species richness than the core area, mainly with species from the regenerating stratum (Slaviero et al. 2014).

The forest fragments in the buffer areas (within a radius of 1 km from the edge of the NPS) are small (< 10 ha) and are isolated from the largest fragment (SERTÃO 2015). These fragments are elongated, narrow (ranging from 50 to 160 meters in width), and usually associated with streams. Fragments are subject to the edge effect, which in most cases affects the entire fragment area. Vegetation tends to be lower and less diverse than in the other study areas. In these areas, the intermediate regeneration stage predominates, with sites of the early regeneration stage at the edges (SERTÃO 2015).

In each environment, with different forest structures, three sample transects were established, according to the following definitions: Core area transects (Core area 1, Core area 2, and Core area 3) inside the NPS, with at least 250 meters from the edge of the fragment; Edge transects (Edge area 1, Edge area 2, and Edge area 3), situated between 10 and 30 meters from the edge of the NPS (into the fragment); and Buffer transects (Buffer area 1, Buffer area 2, and Buffer area 3), in forest fragments around the NPS, distant 500-1000 meters from the edge of the NPS. All transects, regardless of area, were at least 500 meters apart (Fig. 1).

For each transect, four sampling points were established, 100 meters apart, totaling 300 meters in length. A distance of up to 100 meters is recommended so that individuals are not counted more than once and to generate sample independence (Santos Junior et al. 2016; Mammides et al. 2016).

To record species richness and abundance of birds, the point count method was used (Blondel et al. 1970). Two observers remained at each point for 15 minutes and recorded birds sighted and/or heard. Birds within a radius of up to 30 meters from the counting point and only those active in the evaluated environment were recorded (*e.g.*, birds in flight were not recorded). By this method, each counting point is considered as a sample unit, and was used to calculate the Punctual Abundance Index (PAI) (Blake 2007).

The surveys were carried out from November 2020 to February 2021, which corresponds to the breeding season of most bird species. Observations were performed between 5:45 am and 9:45 am. Two transects were sampled per day, alternating the start time between transects and sample areas. Each transect was sampled eight times, totaling 64 samples.

Birds recorded during displacements outside the sample transects were considered Occasional Encounter (OE) and were not used in comparative analyses between areas. Photographic records and vocalizations, when possible, were performed and used to identify or confirm the identification of species. Species were identified with the help of field guides and specialized literature (Sick 2001; Sigrist 2014; Meller 2017; Jacobs and Fenalti 2020). The nomenclature and taxonomic order adopted followed the proposal by the Brazilian Committee of Ornithological Records (Pacheco et al. 2021).

The bird species recorded were categorized according to their feeding habits, habitat use and sensitivity to forest fragmentation. The ecological traits of feeding habits and habitat use of the birds were determined according to descriptions in the literature (Willis 1979; Sick 2001). Feeding habit categories for birds in the NPS and its surroundings were: Carnivorous (CAR, captures and consumes other animals, mainly vertebrates), Detritivorous (DET, consumes carcasses of dead animals), Frugivorous (FRU, consumes mainly fruits), Granivorous (GRA, consumes mainly grains and seeds), Insectivorous (INS, specializes in the consumption of insects), Nectarivorous (NEC, consumes mainly nectar), and Omnivorous (OMN, wide and varied diet, able to consume different foods). The following habitat use categories were recorded for birds in the NPS and its surroundings: Broad (BRO, can occupy different habitats, including anthropic areas),

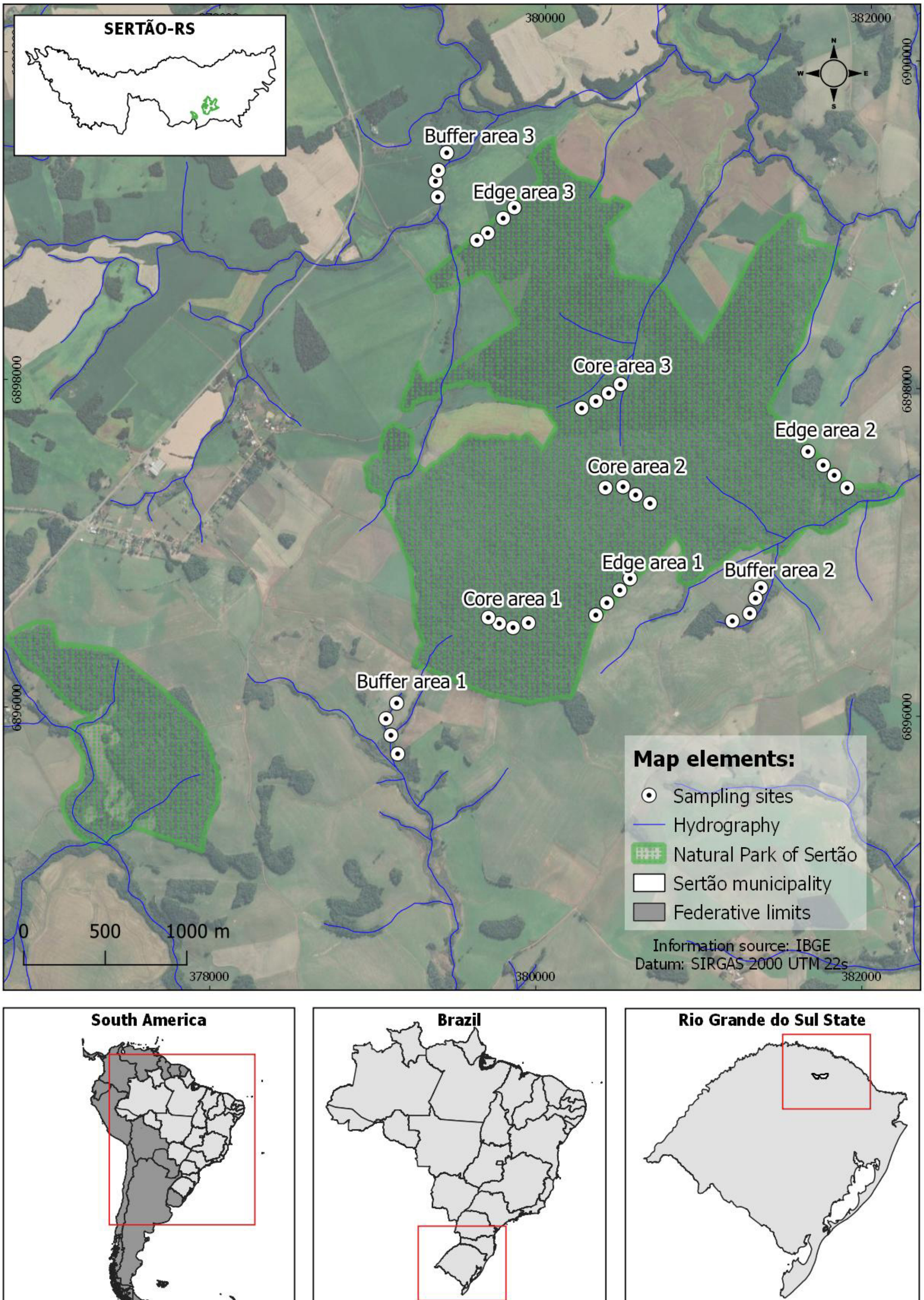

Fig. 1. Study area transects and sampling points in the Natural Park of Sertão (NPS), southern Brazil. Core areas 1, 2 and 3; Edge areas 1, 2, and 3; and Buffer areas 1, 2 and 3.

Open area (OA, mainly occupies open areas such as grasslands and savannas), Wetlands (WET, occurs mainly in flooded areas, such as ponds and rivers), Forest edge (FE, occupies transition areas between forested and open areas), and Forest (FOR, occupies the interior of forested areas). Birds were categorized with High, Medium or Low sensitivity to forest fragmentation as described primarily by Stotz et al. (1996) and Anjos (2006).

Data analysis

To compare the similarity between species composition, in different structures of forest environments, a Cluster Analysis (Cluster-UPGMA) was calculated using the Bray-Curtis Index. Also, we used the Jaccard similarity coefficient (Sij) to compare the similarity between areas. Data normality was assessed using the Shapiro-Wilk test and homogeneity using the Levene test. Comparisons between areas (Core area, Edge area, and Buffer area) for the number of species and for the ecological traits of food habits and habitat use (number of species recorded per transect and per sampling) were made using an analysis of variance (One-way ANOVA) and the Tukey post-hoc test. Comparisons of sensitivity to forest fragmentation (number of species recorded in each category per area) were performed using the Kruskal-Wallis test and Dunn *post-hoc* test. The diversity between the three areas was compared using the Shannon H' diversity index. To test whether H' values obtained in each area differ from each other, the *t*-test for specific diversity was used. Analyses were performed using the PAST 4.06 program (Hammer et al. 2001).

RESULTS

A total of 131 bird species distributed in 18 orders and 38 families were documented (Appendix 1). Of these, 106 were recorded in the transects and another 25 as occasional encounters. The total number of species observed represents 6.64% of the birds recorded in Brazil (Pacheco et al. 2021) and 18.42% of the birds recorded in the Rio Grande do Sul state (Jacobs and Fenalti 2020). The most represented families were Thraupidae (N = 18) and Tyrannidae (N = 16).

The largest number of bird species was recorded in the Buffer area (N = 74) followed by the Edge area (N = 73) and the Core area (N = 59). Although the number of species in the Core area was lower, there was no difference in the number of species recorded between the three areas ($F = 0.012$; $p = 0.98$; Fig. 2). The species diversity index, considering the three sampling areas, was H' = 3.93. Among the sampled areas, the greatest diversity was presented in the Edge area (H' = 3.89), followed by the Buffer area (H' = 3.85) and the Core area (H' = 3.65). There was a significant difference in the diversity index between the Core and Edge areas ($t = -2.55$; $p = 0.01$), and between the Core and Buffer areas ($t = 2.21$; $p = 0.02$). There was no difference between the Edge and Buffer areas ($t = 0.40$; $p = 0.68$).

Species composition varied among the three areas analyzed. Cluster analysis showed that the species composition of the Core areas differs from that of the other two areas (Fig. 3). Only 35 species (33.02%) of

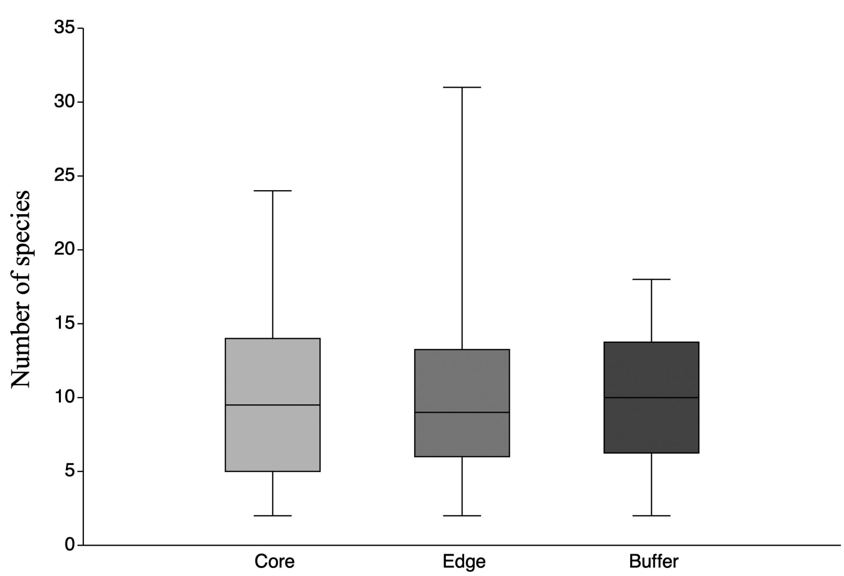

Fig. 2. Number of bird species recorded in the three sampling areas (Core area, Edge area, and Buffer area) in the Natural Park of Sertão (NPS), southern Brazil. Middle line (mean), boxes (mean ± standard deviation), and vertical bars (mean ± conf. interval).

the 106 species found were recorded in the three sample areas. On the other hand, 41 species (38,68%) were exclusive to one area: nine species were found only in the Core area, 14 only in the Edge area, and 18 only in the Buffer area. The similarities were higher between the Edge and Buffer areas (S = 0.67; 50 species), followed by the Core and Edge areas (S = 0.65; 44 species), and the lowest similarity was observed between the Core and Buffer areas (S = 0.59; 41 species).

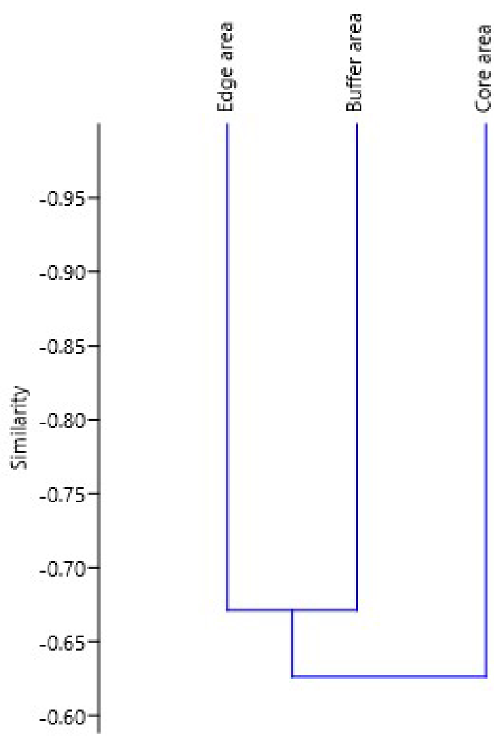

Fig. 3. Dendrogram based on Bray-Curtis dissimilarity to species composition in the three sampling areas (Core area, Edge area, and Buffer area) in the Natural Park of Sertão (NPS), southern Brazil.

The average Punctual Abundance Index (PAI) was 0.18. All species with PAI > 0.18 (N = 22) occurred in the Edge and Buffer areas. Two of these species were not recorded in the Core area. When considering the PAI per sample area, the Buffer area showed more species with PAI > 0.18 (N = 16), followed by the Edge area (N = 14) and Core area (N = 12).

There was a difference in the average number of species with certain ecological traits between the areas. Omnivorous species were found more in the Buffer area than in the Core area. Broad habitat species were more frequent in the Buffer and Edge areas than in the Core area. Forest habitat species were found more in the Core area than in the Buffer area. There were no significant differences for the other analyzed ecological traits (Table 1; Appendix 2).

Most recorded species (N = 67; 66%) had low sensitivity to forest fragmentation, followed by medium sensitive species (N = 32; 32%), and only two species showed high sensitivity (2%). No indication of the degree of sensitivity to forest fragmentation was found for six species (Appendix 1). Species with low sensitivity predominated in the three sampling areas (Fig. 4). The number of species in the study sites differed based on degree of sensitivity to forest fragmentation. Low sensitivity species were more commonly found in the Buffer area than in the Core area ($H = 7.68$, $p = 0.02$). Medium sensitivity species were more commonly found in the Core and Edge areas than in the Buffer areas ($H = 7.26$, $p = 0.02$). The number of highly sensitive species, due to their low number, did

Table 1. Comparisons of species richness per feeding habit and habitat use of bird species among the tree sampling areas (Core area, Edge area, and Buffer area) through Analysis of Variance with Tukey post-hoc test, Natural Park of Sertão (NPS), southern Brazil

Feeding habitat	Three areas	Core and Edge areas	Core and Buffer areas	Edge and Buffer areas
Carnivorous	$F = 1.21$, $p = 0.30$	-	-	-
Frugivorous	$F = 2.92$, $p = 0.06$	-	-	-
Granivorous	$F = 0.26$, $p = 0.76$	-	-	-
Insectivorous	$F = 0.98$, $p = 0.37$	-	-	-
Nectarivorous	$F = 2.07$, $p = 0.13$	-	-	-
Omnivorous	**$F = 4.38$, $p < 0.01$**	-	**$p = 0.01$**	-
Habitat use				
Broad	**$F = 10.03$, $p < 0.01$**	**$p < 0.05$**	**$p < 0.05$**	**-**
Forest	**$F = 3.44$, $p = 0.03$**	**-**	**$p < 0.05$**	**-**
Forest edge	$F = 1.53$, $p = 0.22$	-	-	-
Open area	$F = 0.96$, $p = 0.38$	-	-	-
Wetlands	$F = 0.50$, $p = 0.60$	-	-	-

not vary between areas (H = 3.20, $p = 0.09$; Table 2; Appendix 2). No threatened species were recorded in NPS during this study.

DISCUSSION

The number of species recorded (N = 131) seems to reflect the richness of birds for the NPS and its surroundings. In previous studies carried out at the NPS, which served as the basis for the management plan of the Park (Rezende and Agne 2014), a few more species were recorded than in our study (N = 154), through sampling fieldwork and the addition of bibliographic data.

The number of species recorded in the NPS and its surroundings is similar to that observed in other protected areas also located in fragmented landscapes with intense agricultural use in the south of the Atlantic Forest. In the Passo Fundo National Forest (1358 ha; 30 km from the NPS), characterized by the Mixed Ombrophilous Forest in different stages of regeneration, 129 bird species were recorded (PLANO DE MANEJO DA FLORESTA NACIONAL DE PASSO FUNDO 2011). In the Mata do Rio Uruguai Teixeira Soares Municipal Natural Park (431 ha; 65 km from the NPS), Mikolaiczik et al. (2019) recorded 145 bird species, evaluating the influence of forest regeneration stages on the richness and species composition in the transition between Seasonal Deciduous Forest and Mixed Ombrophilous Forest. In Fritz Plaumann State Park (717.48 ha; 82 km from the NPS), also under the influence of the Seasonal Deciduous Forest, 221 bird species were recorded (field and bibliographic survey) in the park and buffer zone (PLANO DE MANEJO FASE II DO PARQUE ESTADUAL FRITZ PLAUMANN 2014).

In forest fragments outside the protected areas, but also in fragmented landscapes at the south of the Atlantic Forest, the number of species remains similar. In a forest area in the municipality of Augusto Pestana (236.4 ha; 180 km from the NPS), 126 species of birds were recorded among the Core, Edge, and Buffer areas (Jacoboski et al. 2014a). In a forest fragment of about 200 ha (185 km from the NPS), 87 bird species were recorded, considering the Core and Edge areas of the

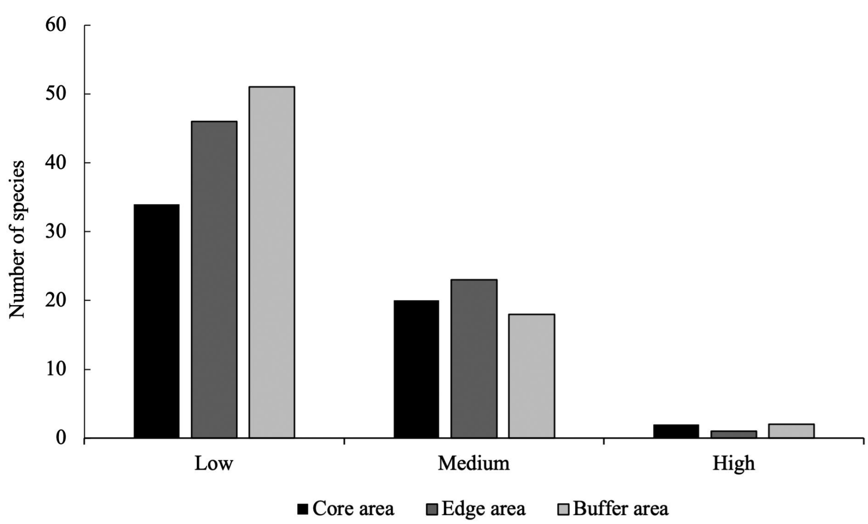

Fig. 4. Number of bird species per sensitivity level to forest fragmentation in the three sampling areas (Core areas, Edge areas, and Buffer areas) in the Natural Park of Sertão (NPS), southern Brazil.

Table 2. Comparisons of bird species sensitivity level to forest fragmentation among the tree sampling areas (Core areas, Edge areas, and Buffer areas) through Kruskal-Wallis with Dunn post-hoc test, Natural Park of Sertão (NPS), southern Brazil

Sensitivity	Three areas	Core and Edge areas	Core and Buffer areas	Edge and Buffer areas
Low	**H = 7.68, $p = 0.02$**	-	**$p < 0.05$**	-
Medium	**H = 7.26, $p = 0.02$**	-	**$p < 0.05$**	**$p < 0.05$**
High	H = 3.20, $p = 0.09$	-	-	-

forest fragment (Jacoboski et al. 2014b). A richness of 165 bird species was recorded by Teixeira and Pardini (2009) in the municipality of Frederico Westphalen (area of about 100 ha; 120 km from the NPS) in a landscape formed by a mosaic of small forest fragments and characterized by agriculture.

Our results showed that the Core areas differs from the Edge and Buffer areas due to the difference in the diversity index, as well as in the species composition. On the other hand, the species composition was similar between the Edge and Buffer areas. This fact may be associated with the structural similarities of the Edge and Buffer areas (see description in Methods and in Slaviero et al. 2014). The low percentage of species that occurred in the three environments (33%) and the percentage of species that occurred in just one area (38%) confirm the differences in diversity and species composition.

Bird responses to human interventions range from those that have benefited from habitat changes and increased their populations, to those that are excluded locally from environments (Marini and Garcia 2005). In the Edge and Buffer areas of the NPS, more species were found with the highest Punctual Abundance Index (PAI). According to Forman and Godron (1986), the intermediate disturbance of an area tends to promote heterogeneous landscape, and the absence of disturbance tends to a homogenization of the landscape. The Edge and Buffer areas seem to have more heterogeneity of environments/substrates (Slaviero et al. 2014), which allows for a greater occurrence of species, with a greater abundance of birds with flexibility in behavior and broad environmental tolerance.

The results regarding the ecological traits of the species reinforce the influence of the different structures of the environments on the distribution of birds in the NPS and its surroundings. Omnivory is a common trophic category in Neotropical birds, mainly in birds from open or forested areas under anthropic influence (Willis 1979; Sick 2001). A large number of omnivorous species is a characteristic of smaller forest fragments, as well as areas of secondary vegetation, due to the fact that omnivorous species adjust more easily to these types of environments (Mikolaiczik et al. 2019).

The high number of omnivorous species recorded in the Edge and Buffer areas of the NPS may be related to the forest structure of these environments. The alterations in the forest structure generated by the edge effect may provide an environment with broad characteristics of resources and habitats (Colles et al. 2009). The ability to use different food resources may favor omnivorous species in areas of heterogeneous forest structure (Anjos et al. 2019), such as the species recorded in the Edge and Buffer areas in this study.

The high number of Forest habitat species in the Core areas, and of Broad habitat species in the Edge and Buffer areas, corroborate the proposal of the influence of the different structures of the vegetation cover on the bird fauna in the NPS and its surroundings. The Core areas have a more homogeneous vegetation structure, with a denser and higher canopy (Slaviero et al. 2014) and can be considered a refuge for species primarily from forest environments.

Different bird species have different levels of sensitivity to environmental structure changes. Clearly, there are species that show different sensitivities to forest fragmentation (Parker III 1996; Uezu et al. 2005; Martensen et al. 2008). However, it is important to consider that the sensitivity levels of bird species vary according to the differences in landscape fragmentation (Anjos 2006). Our results show a small number of species that are highly sensitive to forest fragmentation in the study area. The tendency of the most sensitive birds is to disappear over time as changes in the landscape result in further degradation of the environment.

The variety of structurally different environments can result in a diversity of environmental resources and favor species that are less sensitive to forest fragmentation. On the other hand, greater homogeneity in the landscape may favor species sensitive to disturbances, which need large areas of internal habitat, far from the area of edge effect (Crooks et al. 2001; Bolger et al. 2001). The difference in the number of species of low sensitivity between the Core and Buffer areas, as well as the difference recorded in medium sensitive species between the Core and Buffer areas and between the Edge and Buffer areas, can be a consequence of the landscape structure on the occurrence of species in each sample area analyzed in the NPS.

Although the Edge and Buffer areas have greater diversity, the Core areas showed great importance in maintaining species that are more sensitive to forest fragmentation. If the most conserved habitat areas are reduced, birds that are more demanding in relation to the quality of the environment will disappear over time (Leck 1979; Whitmore 1997). On the other hand, if this fragmentation occurs, numbers of less sensitive species may increase, such as we observed among omnivorous species and those that use broad habitat types in the Edge and Buffer areas. Even the largest fragments, considering the regional context, such as the NPS, may have bird fauna mainly composed of widely distributed species that are less sensitive to forest fragmentation. Species that prefer forest habitats may no longer occur or be restricted to the core areas of the fragments with reduced populations. This may be indicated by the small number of species with high sensitivity. These species may have already been excluded due to the absence or low availability of preserved environments.

CONCLUSIONS

In conclusion, the present work shows that the diversity and species composition in the three sampled areas seem to be explained by the ecological traits and the sensitivity of bird species to forest fragmentation, which in turn seems to reflect different forest structures in the NPS and its surroundings. For conservation of bird fauna in the NPS, the maintenance of the core areas is essential, especially for species that require a structurally preserved environment.

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Competing interests: CB, MH and PH declare that they have no conflicts of interest.

Availability of data and materials: The data supporting the findings of this study are available within the article and its supplementary materials.

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Ethics approval consent to participate: Not applicable.

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Supplementary materials

Appendix 1. Bird species recorded (X) in the tree sampling areas (Core, Edge and Buffer areas) in the Natural Park of Sertão (NPS), southern Brazil. Occasional encounter (OE). Feeding habits (FH): Carnivorous (CAR), Detritivorous (DET), Frugivorous (FRU), Granivorous (GRA), Insectivorous (INS), Nectarivorous (NEC), Omnivorous (OMN). Habitat use (HU): Broad (BRO), Forest (FOR), Forest edge (FE), Open area (OA), Wetland (WET). Sensitivity level to forest fragmentation (Sen): Low (L), Medium (M), High (H), - The authors agree with the suggestion. Punctual Abundance Index (PAI). Species without PAI value were recorded by Occasional encounter. (download)

Appendix 2. Number of species (N), mean and standard deviation (mean ± SD) by ecological traits and the level of sensitivity in the tree sampling areas (Core areas, Edge areas, and Buffer areas) in the Natural Park of Sertão (NPS), southern Brazil. (download)