LRH: de-Carvalho et al.

RRH: Isolated Trees Support Bird Functional Diversity

Isolated trees support lower bird taxonomic richness than trees within habitat patches but similar functional diversity

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ABSTRACT

Large isolated trees are keystone structures that can help maintain biodiversity in fragmented landscapes, with evidence that open areas with isolated trees may support similar levels of taxonomic diversity to nearby patches of habitat. However, it is not clear if isolated trees can support the same diversity of ecological functions as trees in habitat patches. We compared species richness, community composition and functional diversity of birds in trees at forest edges and isolated trees. Twenty isolated trees and ten edge trees of American muskwood (*Guarea guidonia*) were selected, and sampled on 11 occasions, each of 20 minutes, over four months. All individual birds that landed at trees were recorded using a standardized protocol. Species richness was, on average, almost twice as high at edge trees than at isolated trees. Taxonomic composition differed between edge and isolated trees, with many forest-dependent birds restricted to edge trees, and some open-area birds restricted to isolated trees. Overall functional diversity was similar at edge and isolated trees, but some ecological functions (e.g. frugivory) were less frequent, while others (e.g. granivory) were more frequent at isolated compared to edge trees. Isolated trees are important for supporting many ecological functions in modified areas. However, the maintenance of forest patches is essential to complement the provision of such functions in modified landscapes.

Keywords: Atlantic Forest; Brazil; fragmented landscapes; functional traits; matrix suitability; Functional divergence index; scattered trees.

RESUMO

Árvores isoladas são estruturas-chave que podem ajudar a manter a biodiversidade em paisagens fragmentadas, com evidências de que áreas abertas com árvores isoladas podem suportar níveis semelhantes de diversidade taxonômica quando comparadas a fragmentos florestais próximos. No entanto, não está claro se as árvores isoladas podem suportar a mesma diversidade de funções ecológicas que árvores localizadas em fragmentos florestais. Para testar isso, comparamos a riqueza de espécies, a composição da comunidade e a diversidade funcional de aves em árvores isoladas e árvores localizadas nas bordas da floresta. Vinte Carrapeteiras (*Guarea guidonia*) isoladas e dez localizadas na borda da floresta foram selecionadas, e amostradas por 20 minutos em 11 ocasiões, durante quatro meses. Todas as aves que pousaram nas árvores foram registradas usando um protocolo padronizado. A riqueza de espécies foi, em média, duas vezes mais alta em árvores localizadas na borda do que em árvores isoladas. A composição taxonômica diferiu entre árvores localizadas na borda e isoladas, com muitas aves dependentes de floresta restritas às árvores localizadas na borda e algumas aves de área aberta restritas às árvores isoladas. Por outro lado, a diversidade funcional foi semelhante nas árvores localizadas na borda e isoladas, mas algumas funções ecológicas (e.g., frugivoria) foram menos frequentes, enquanto outras (e.g., granivoria) foram mais frequentes nas árvores isoladas em comparação com as árvores localizadas na borda. Árvores isoladas são importantes para manter funções ecológicas em áreas modificadas. No entanto, a manutenção de áreas florestais é essencial para complementar o fornecimento de tais funções.

THE CONVERSION OF NATIVE HABITATS TO HUMAN-MODIFIED ENVIRONMENTS IS A MAJOR CAUSE OF BIODIVERSITY LOSS WORLDWIDE (Donald et *al.* 2001; Norris 2008; Scherr & McNeely 2008; Butchart *et al.* 2010; Newbold *et al.* 2015; Tilman *et al.* 2017). It is clear that patches of old-growth vegetation are essential for sustaining biodiversity (Ewers & Didham 2006; Gibson *et al.* 2011; Betts *et al.* 2017; Watson *et al.* 2018). However, given multiple competing demands for land, the conservation of native habitat remnants is sometimes not possible and in other cases insufficient to conserve all biodiversity (Cullen *et al.* 2004; Rodrigues *et al.* 2004; Phalan *et al.* 2011; Fischer *et al.* 2014). Thus, managing the matrix in fragmented landscapes may be key to maintain biodiversity, ecosystem services and agricultural production (Schroth *et al.* 2004; Lindenmayer *et al.* 2008; Fischer *et al.* 2014).

One strategy to increase matrix suitability for biodiversity is to maintain or plant isolated trees (Manning *et al.* 2006; Prevedello *et al.* 2018). Such trees are thought to be “biodiversity foci” as they may facilitate the occurrence of native species in open areas (Dunn 2000; Fischer & Lindenmayer 2002a; DeMars *et al.* 2010; Lindenmayer & Laurance 2016; Prevedello *et al.* 2018). Furthermore, isolated trees may increase the provision of ecosystem services such as pest control, pollination of crops, and increase livestock production by offering shade and shelter for cattle (Quelch 2002; Fischer *et al.* 2010; Barton *et al.* 2016). Therefore, isolated trees have been considered "keystone structures" in fragmented landscapes due to their disproportionately high contribution to ecosystem functioning relative to the small area they occupy (Fischer *et al.* 2010). A recent meta-analysis provided quantitative support for the “keystone tree hypothesis” for arthropods, vertebrates and terrestrial plants, showing that open areas near isolated trees may support similar species abundance and richness to areas within habitat patches (Prevedello *et al.* 2018).

Despite increasing recognition of the importance of isolated trees, previous studies have focused on species richness and taxonomic composition only (e.g. Dunn 2000; DeMars *et al.* 2010; Fischer *et al.* 2010; Lasky & Keitt 2012), whereas the role of isolated trees in the maintenance of functional diversity is poorly understood. Recent studies have evaluated how functional diversity responds to different anthropogenic impacts (e.g. De Coster *et al.* 2015, Magioli et al. 2016), but to our knowledge no study has addressed communities of isolated trees from a functional perspective. Although the biotic communities using isolated trees may be composed by a mix of species from open areas and from habitat patches (Prevedello *et al.* 2018), it is unclear whether isolated trees may support similar levels of functional diversity to trees located within habitat patches. Therefore, quantifying which ecological functions these species can provide in modified areas is essential to inform future conservation and management initiatives.

To assess the contribution of isolated trees to the maintenance of both taxonomic and functional diversity, we compared species richness, community composition, and functional diversity of birds between isolated trees and trees located at the edges of continuous forests. We hypothesized that: (i) isolated trees will be used by a smaller number of forest-dependent species and a higher number of open-area species compared to edge trees, as the communities using isolated trees appear to be composed by a mix of species from open areas and from habitat patches (Prevedello *et al.* 2018); and (ii) despite possible taxonomic differences, functional diversity will be similar between communities from isolated and edge trees, as found in previous studies comparing taxonomic and functional diversity (e.g. De Coster *et al.* 2015, Magioli et al. 2016). To test these predictions, we conducted an empirical study in a biodiversity hotspot - the Brazilian Atlantic Forest (Myers *et al.* 2000; Ribeiro *et al.* 2009), using birds as model organisms, and quantified their taxonomic and functional diversity and vulnerability to habitat loss and fragmentation (Marini & Garcia 2005; BirdLife International 2013).

METHODS

STUDY AREA – We conducted this study in forests and pastures located within and adjacent to the Reserva Ecológica de Guapiaçu (REGUA; 22°24’S, 42°44’W), in Rio de Janeiro state, Brazil. The study landscape is composed of a mosaic of native forests surrounded by pastures (Vieira *et al.* 2009; Almeida-Gomes & Rocha 2014) that have been semi-cleared for ~ 100 years. The pastures support large numbers of livestock and many isolated trees - mostly of American muskwood (*Guarea guidonia*; Meliaceae) and fig trees (*Ficus* spp.; Moraceae), as well as guava (*Psidium guajava*; Myrtaceae), gumtree (*Sapium glandulosum*; Euphorbiaceae) and cambara (*Gochnatia polymorpha*; Asteraceae).

SAMPLING DESIGN – We carefully selected trees for sampling, controlling possible confounding factors. To control for potential differences in the attractiveness of different tree species to birds, we focused on a single tree species, American muskwood (*G. guidonia*), which is the dominant isolated tree in the study area (A. D. Azevedo, unpublished data) and common throughout the Atlantic Forest (Cartes 2003; Lima *et al.* 2009). We measured and georeferenced 102 *G. guidonia* trees within the study landscape and selected 20 isolated trees and 10 edge trees based on a careful systematic procedure (Fig. S1). First, we selected trees that were at least 200 m apart, to prevent double counting of birds and to maximize the independence of sampling units (trees). Second, we selected trees spanning a broad range of sizes (i.e. circumference at breast height). Tree size varied from 0.87 to 5.84 m (mean ± SE: 2.32 ±1.27) among isolated trees and from 0.5 to 2.12 m (1.27 ± 0.64) among edge trees. Third, isolated trees varied in the number of surrounding isolated trees (from all species) and in the amount of surrounding forest cover, thus covering the range of conditions present within our study landscape. Forest cover varied from 0 to 57 percent, the number of isolated trees ranged from 0 to 34, within a 200-m radius circular area around sampled isolated trees, and the distance from the forest edge varied from 12 to 2,145 m. Edge trees were located at the edge of a large continuous forest area of ~ 100,000-ha (Fig. S1). Thus, the edge trees served as a reference to determine the potential pool of bird species present at the edges of continuous forest that might use the sampled isolated trees. Fruit density, i.e., the volume of the canopy with fruits estimated by counting and attributing a score from 0 to 5, was similar at isolated and edges trees within our survey period (mean density ± SD per tree = 2.19 ± 1.57 and 1.55 ± 0.61 for isolated and edge trees, respectively; t-Student = 1.47; p = 0.15). We sampled a higher number of isolated trees (20) than edge trees (10) to capture the range of variation in distances from the continuous forest and in the amount of surrounding forest cover in the isolated trees. This difference in the number of sampled trees did not affect our comparisons of bird communities between the two treatments, as the individual trees were used as the unit of analysis for statistical modelling (see *Data analysis*).

BIRD SAMPLING – We sampled birds from September to December 2016, which corresponded to the period of greatest reproductive activity (Sick 1997). Based on a pilot study conducted in September 2015 and information in the literature (Fischer and Lindenmayer 2002a, b; DeMars *et al.* 2010), we determined 20 minutes to be the appropriate period for sampling. During each 20-min sampling event, an observer stood at 5 m from a sampled tree (ideal distance for bird identification) and recorded all birds that landed at the tree. Surveys were conducted between 5:00 and 11:00 a.m. and only during fine weather, with the same amount of effort employed for all trees. All trees were sampled in each of the four months of the study at all survey hours, summing to 11 sampling events of 20 min each (220 min in total for each tree).

FUNCTIONAL TRAITS – To quantify functional diversity, we selected bird traits related to habitat requirements (open area, generalist, or forest; Stotz 1996, del Hoyo *et al.* 2020), diet (carnivore, frugivore, nectarivore, granivore, insectivore, saprophage, or omnivore; Wilman et al. 2014), foraging strata (terrestrial, understory, midstory, superior, or generalized; Stotz 1996, Wilman et al. 2014) and body mass (small – individuals smaller than the median, i.e. 24.75 g, and large – individuals larger than the median; Dunning 2007), which are related to both the response of species to environmental change and their effects on ecosystem function (Luck *et al.* 2012). Therefore, we compiled data for a total of four traits containing 16 categories (Table S2). The traits classification was based on available information in the literature (e.g. Stotz 1996, Dunning 2007, Wilman et al. 2014, del Hoyo *et al.* 2020).

DATA ANALYSIS – To guarantee a robust sampling effort to capture the set of species using each tree, we pooled the data from the 11 sampling events per tree to quantify differences in composition and compute taxonomic and functional diversity. To evaluate differences in bird community composition between isolated and edge trees, we completed non-metric multidimensional scaling (NMDS) based on Jaccard distances (presence-absence of species).

To compare species richness between isolated and edge trees, we built a GLM with negative binomially-distributed residuals, as the residuals were overdispersed ($c = 2.06$, $p = 0.05$). We controlled for differences in tree size by including diameter at breast height (DBH) as a co-variable in the model, as tree size varied significantly between treatments (t-Student = -2.44; $p = 0.02$); and for differences in distance of isolated trees to the nearest forest edge. To evaluate the differences in functional diversity between isolated and edge trees, we used a functional divergence index (FDiv), which has a high power to detect assembly rules as functional dissimilarity (limiting similarity) and redundancy (niche filtering) (Mouchet et al. 2010). High levels of functional divergence are associated with niche differentiation among species (Mouchet et al. 2010). We used Gower's distance to build a matrix of dissimilarity (Botta-Dukat 2005) using the FD package (dbFD function; Laliberté *et al.* 2014). To compare the functional diversity (FDiv) between treatments, we built a GLM with Gaussian distribution, as the residuals were normally distributed (Shapiro Wilk w = 0.98, p = 0.90; Fig. S3), controlling for tree size and distance of isolated trees to the nearest forest edge, which were used as co-variables. We found no correlation between species richness and FDiv (Pearson's r = 0.18; p = 0.35).

To identify changes in frequency across categories within each trait (habitat requirements, diet, foraging strata, and body mass) between edge and isolated trees, we performed a multinomial logistic regression using the VGAM package (Yee 2013), considering the number of species in each category recorded in each tree. We used generalist species, omnivorous species, generalized species, and small species (< 24.75 g) as reference groups for habitat requirements, diet, foraging strata, and body mass, respectively. We conducted all analyses in the R environment (R Development Core Team 2017).

RESULTS

We recorded a total of 117 bird species from 37 families, with 95 species from the 10 edge trees and 78 species from the 20 isolated trees. We recorded 39 species (33%) exclusively at edge trees, and 22 (19%) exclusively at isolated trees (Table S4). Accordingly, there were clear differences in community composition between edge and isolated trees (stress = 0.15; Fig. 1).

Species richness differed significantly between edge and isolated trees ($z = -4.76$; $p < 0.001$) (Fig. 2A) with, on average, 70 percent more species observed at an edge tree compared to an isolated tree. In contrast, functional diversity was similar between isolated and edges trees (t = -0.42; p = 0.68) (Fig. 2B).

The frequency of categories within traits differed between edge and isolated trees. We observed a statistically significant decrease in the frequency of forest species ($p < 0.001$) and an increase in frequency of open species ($p < 0.001$) from edge to isolated trees (Table 1, Fig. 3A). We found a significant reduction in frequency of frugivorous species and an increase in frequency of granivorous species from edge to isolated trees (Table 1, Fig. 3B). We also found a significant reduction in frequency of midstory and understory species from edge to isolated trees (Table 1, Fig. 3C). Finally, the frequency of body mass categories was similar between edge and isolated trees (Table 1, Fig. 3D).

DISCUSSION

Our results supported our two hypotheses, indicating that isolated trees support bird communities with fewer and different species compared to trees at forest edges, but with similar levels of functional diversity. However, the frequency of categories within three distinct functional traits differed between edge and isolated trees. In the remainder of this section, we first discuss the differences in species composition and species richness between edge and isolated trees. We then discuss the similarity in functional diversity between these two types of trees. We conclude highlighting the implications of our findings for the maintenance of biodiversity and ecosystem services in human-modified landscapes, as well as the relevance of investigating changes in species functional traits when assessing functional diversity.

SPECIES COMPOSITION AND RICHNESS – Similar to previous studies (e.g. Fischer & Lindenmayer 2002a; Prevedello *et al.* 2018), we found a clear difference in species composition between isolated and edge trees. This difference was due mostly to a replacement of forest-dependent species by open-area species at isolated trees. Previous studies have found that many forest species are negatively affected by forest loss (Watson *et al.* 2018), whereas open-area species generally exhibit a positive response (e.g. Estavillo *et al.* 2013; Morante-Filho *et al.* 2015). Our results therefore reinforce the importance of habitat patches for disturbance-sensitive birds. Importantly, however, some forest-dependent species also were present at isolated trees, even if uncommon, confirming that isolated trees support a mix of species from open areas and habitat patches, as recently found in an earlier investigation (Prevedello *et al.* 2018).

Consistent with our predictions at the outset of this study, we detected greater bird species richness at edge trees compared to isolated trees. One third of all bird species were found only at edge trees. However, in a recent meta-analysis, species richness was similar in habitat patches and in areas with isolated trees for many taxa, including vertebrates (Prevedello *et al.* 2018). Our data thus suggest that the species-rich Atlantic forest bird fauna may respond more strongly to tree position (edge versus isolated), compared to the faunas of other tropical and temperate areas. Although we detected more species at edge trees, including one vulnerable species (the Channel-billed Toucan *Ramphastos vitellinus* (IUCN 2019) and 15 endemic species, we also recorded at isolated trees one near threatened species, the Festive Coquette *Lophornis chalybeus* (IUCN 2019), and five endemic species (Vale et al. 2018). In addition, the lower number of species detected at isolated trees may partly reflect a sampling bias, if some birds avoided landing at isolated trees due to the presence of researchers (who could be more easily detected in the open area). Therefore, isolated trees should not be disregarded as unimportant for conservation, especially due their potential to support some threatened and endemic species.

FUNCTIONAL DIVERSITY – When investigating community differences in functional terms, we found that functional diversity (FDiv) did not differ between edge and isolated trees. This may reflect changes in the frequency of traits, rather than the simple loss of some functional traits in the isolated trees compared to edge trees. Relative to edge trees, isolated trees supported a lower number of forest, frugivorous, canopy and midstory species, but a greater number of granivorous and open-area species. This pattern probably reflects the greater availability of fruit and greater vertical complexity of the vegetation in forests compared to open areas with isolated trees, possibly as a result of higher tree density and richness in forests. Indeed, frugivorous birds are generally more sensitive to habitat loss and degradation than granivorous birds (which are more common in open areas; reviewed by Sekercioglu 2012; Bregman *et al.* 2014).

A novel outcome from this investigation was that human-generated open areas with isolated trees had the same functional diversity as observed at forest edges, despite a strong reduction in taxonomic richness and marked changes in species composition. However, the frequency of functional trait categories varied between communities at edge and isolated trees, underscoring the importance of investigating the variation in trait frequency to more thoroughly assess local changes in community composition (De Coster *et al.* 2015).

Our findings revealed that isolated trees are used by birds with potentially important functions in modified areas, such as carnivorous and insectivorous species that may promote pest control. However, the maintenance of large forest patches is essential to complement the provision of important functions in modified landscapes, for example by favoring frugivorous species, which may play an essential role as seed dispersers (reviewed by Sekercioglu 2006).

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DATA AVAILABILITY STATEMENT

Data Availability: The data used in this study will be archived at the Dryad Digital Repository (waiting for article acceptance to archive data).

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TABLE 1. Multinomial logistic regressions to evaluate differences in the frequency of categories within bird traits, from edge trees to isolated trees. Significant p-values are in bold.

	Coefficient (β)	z value	P-value
Habitat requirement			
Generalist	Reference group		
Open	1.224	6.604	**< 0.001**
Forest	-1.542	-3.377	**< 0.001**
Diet			
Omnivore	Reference group		
Carnivore	-0.814	-1.562	0.118
Frugivore	-1.027	-3.314	**< 0.001**
Nectarivore	0.045	0.139	0.889
Granivore	0.995	3.214	**0.001**
Insectivore	0.247	1.208	0.227
Saprophage	-1.508	-1.337	0.181
Foraging strata			
Generalized	Reference group		
Terrestrial	0.464	1.740	0.081
Understory	-0.302	-0.954	0.340
Midstory	-0.505	-2.086	**0.037**
Superior	-0.828	-3.476	**< 0.001**
Body mass			
Small	Reference group		
Large	0.053	0.321	0.748

FIGURE LEGENDS

FIGURE 1. Differences in bird species composition between focal trees located at forest edges (white trees) and isolated in open pasture (black trees). The two axes of a non-metric multidimensional scaling (NMDS) are shown based on presence–absence data of 117 bird species (stress = 0.15)

FIGURE 2. Boxplots showing differences in bird species richness (a), and in functional diversity (FDiv; b) between forest edge (edge) and isolated trees (iso). Each boxplot shows the median (horizontal bars in bold), the quartiles (boxes), the maximum and minimum excluding outliers (bars), and the outlier (circle)

FIGURE 3. Predicted means (black dots) and standard errors (vertical dotted lines) of the frequency of different categories within bird traits at edge and isolated trees. The gray dotted lines represent the reference group for each trait. A – Habitat requirement; B – Diet; C – Foraging strata; D – Body mass. Asterisks represent the significance level (*$0.01 \leq p \leq 0.05$; **$0.001 \leq p \leq 0.01$; ***$p < 0.001$)

FIGURES

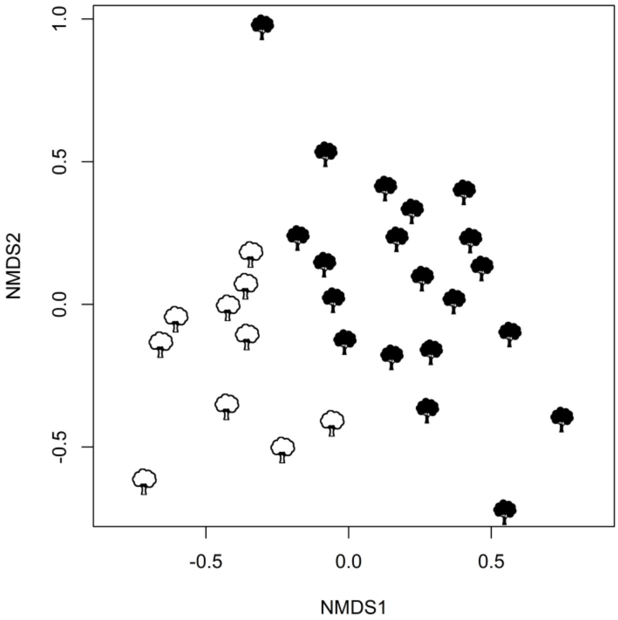

FIGURE 1

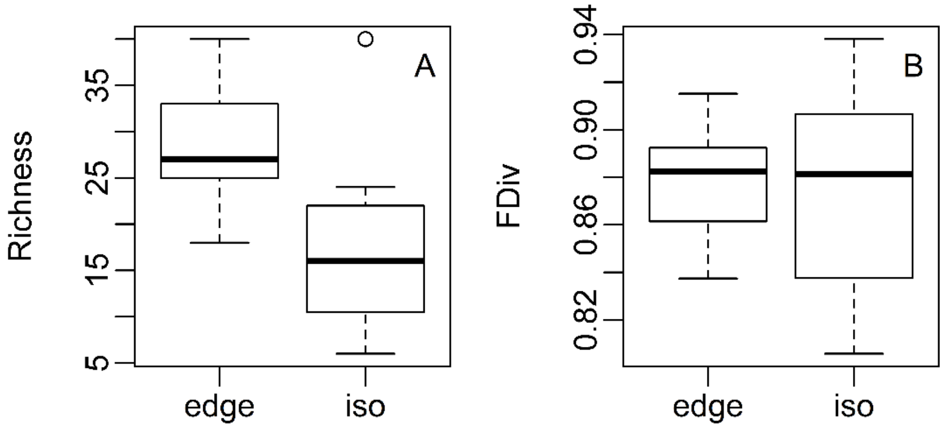

FIGURE 2

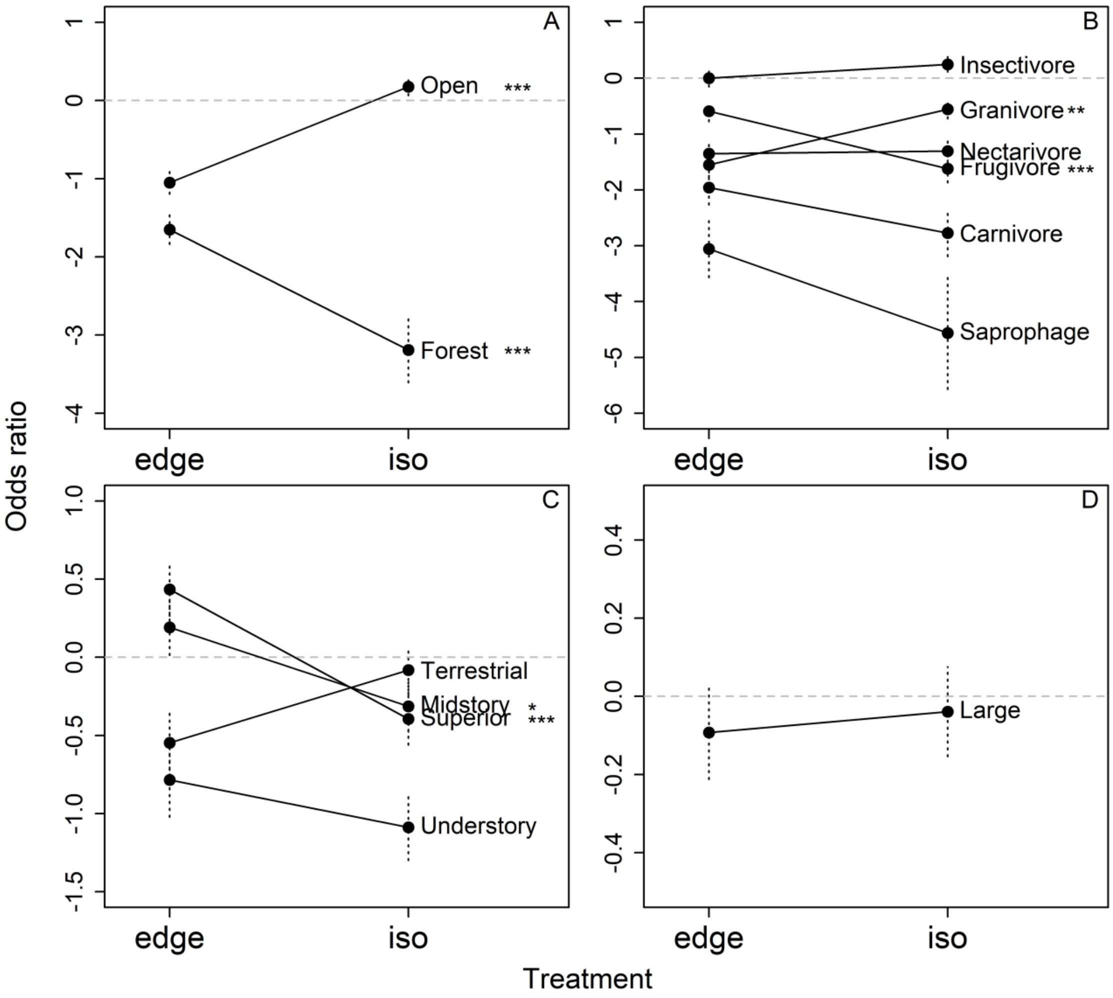
A
B
C
D
Odds ratio
Treatment
edge
iso
Open ***
Forest ***
Insectivore
Granivore **
Nectarivore
Frugivore ***
Carnivore
Saprophage
Terrestrial
Midstory *
Superior ***
Understory
Large
1
0
-1
-2
-3
-4
-5
-6
1.0
0.5
0.0
-0.5
-1.0
-1.5
0.4
0.2
0.0
-0.2
-0.4

FIGURE 3

SUPPLEMENTARY INFORMATION

Isolated trees support lower taxonomic richness than trees within habitat patches but similar functional diversity

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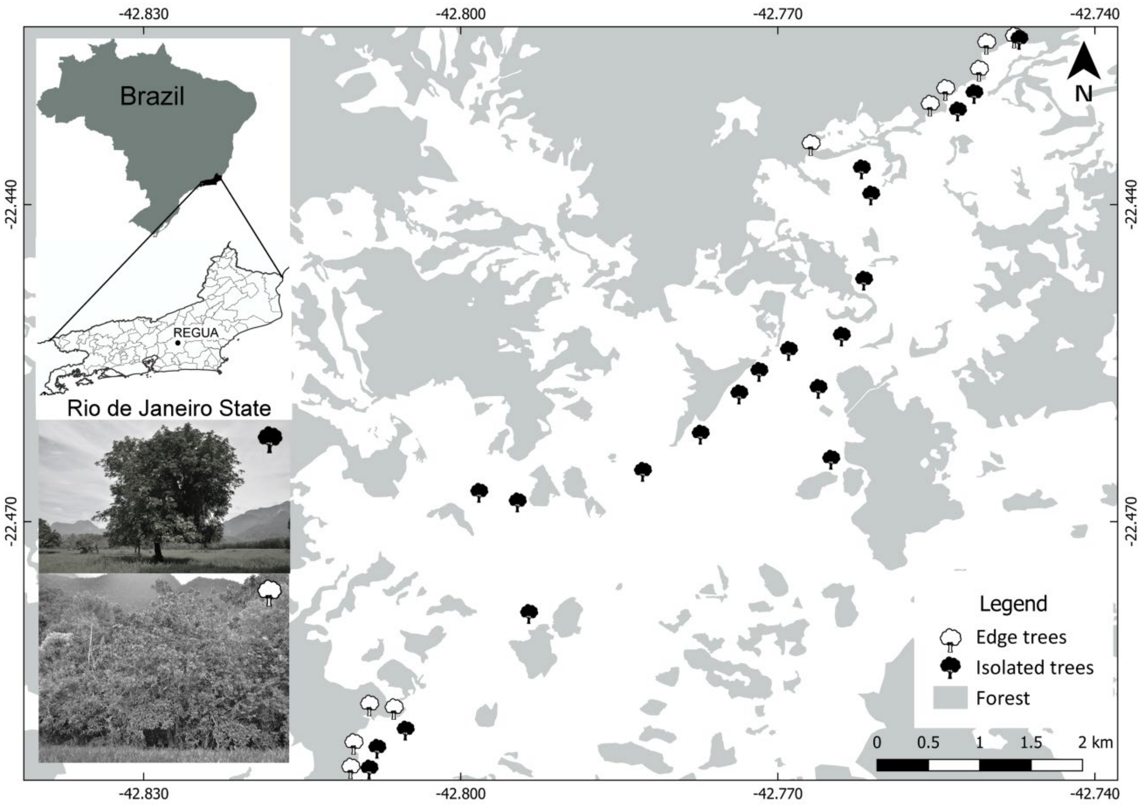

FIGURE S1. Study area and sampling design. A total of 30 focal trees was sampled, ten at forest-pasture edges (white trees) and 20 isolated in open pasture (black trees), in an Atlantic Forest fragmented landscape in Rio de Janeiro, Brazil

TABLE S2. Used traits (a-f), with respective categories and descriptions

Traits	**Descriptions**
a) Habitat requirement	
Forest	Forest specialist birds
Open area	Open area specialist birds
Generalist	Generalists birds
b) Diet	
Carnivore	Feeds mainly on vertebrates
Frugivore	Feeds mainly of fruits
Nectarivore	Feeds mainly on nectar
Granivore	Feeds mainly on seeds
Insectivore	Feeds mainly on arthropods and caterpillars
Carrion eating habit	Feeds mainly on dead animals
Omnivore	No food preference
c) Foraging stratum	
Terrestrial	Fodder mainly on the ground
Understory	Fodder mainly on understory
Midstory	Fodder mainly on midstory
Superior	Fodder mainly on canopy
Generalized	Forage with similar frequency in two or more strata
d) Body mass	
Mass	Average weight between males and females, in grams

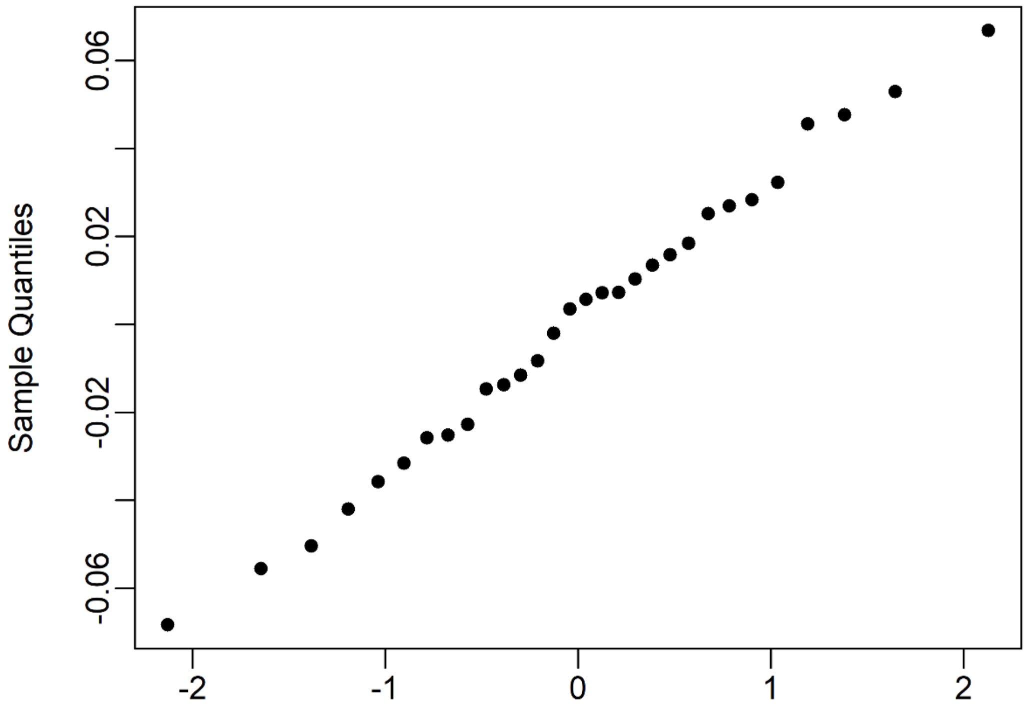

FIGURE S3. Qqplot showing that residuals of bird functional diversity have normal distribution.

TABLE S4. Record birds on edge trees (edge) and at isolated trees (iso) and their respective functional attributes: Habitat requirement (Habitat; Open area – OA; generalist – G; forest – F), diet (frugivore – Fru; granivore – Gra; nectarivore – Nec; carnivore – Car; insetivore – Ins; Carrion eating – Carri; omnivore - Omn), Foraging stratum (For; terrestrial – T, understory – U; midstory – M; superior – S, generalized – Ge) and e body mass (mass; quantitative data, in grams).

Scientific name	**habitat**	**diet**	**for**	**mass**	**iso**	**edge**
Tinamiformes						
Tinamidae						
Crypturellus tataupa	G	Ins	T	221.3		x
Galliformes						
Cracidae						
Penelope superciliaris	G	Fru	Ge	815		x
Cathartiformes						
Cathartidae						
Cathartes aura	OA	Sap	T	1425		x
Coragyps atratus	OA	Sap	T	1520	x	x
Accipitriformes						
Accipitridae						
Geranospiza caerulescens	G	Car	M	321.5		x
Heterospizias meridionalis	OA	Car	Ge	904.5	x	x
Rupornis magnirostris	G	Car	Ge	269	x	x
Gruiformes						
Aramidae						

Aramus guarauna	OA	Omn	T	1137.5	x	
Columbiformes						
Columbidae						
Columbina talpacoti	OA	Gra	T	45.6	x	
Claravis pretiosa	G	Gra	T	62.5	x	x
Patagioenas picazuro	G	Gra	Ge	402	x	x
Leptotila verreauxi	G	Gra	T	126.5		x
Cuculiformes						
Cuculidae						
Piaya cayana	G	Ins	S	102	x	x
Coccyzus sp.	G	-	-	-		x
Crotophaga ani	OA	Ins	Ge	124.5	x	x
Guira guira	OA	Ins	T	144.6	x	x
Tapera naevia	OA	Ins	T	49.5		x
Strigiformes						
Tytonidae						
Tyto furcata	OA	Car	T	472.5	x	
Caprimulgiformes						
Caprimulgidae						
Nyctidromus albicollis	G	Ins	T	55.3	x	
Apodiformes						
Apodidae						
Chaetura meridionalis	G	Ins	S	21.5		x
Trochilidae						
Ramphodon naevius	F	Nec	U	7.9		x

Glaucis hirsutus	G	Nec	U	6.1		x
Phaethornis pretrei	G	Nec	U	3.8		x
Eupetomena macroura	OA	Nec	M	7.7	x	x
Florisuga fusca	G	Nec	M	8	x	x
Lophornis chalybeus	G	Nec	M	3	x	
Chlorostilbon lucidus	G	Nec	M	3.6		x
Thalurania glaucopis	G	Nec	Ge	4.5	x	x
Hylocharis sapphirina	G	Nec	U	4.2		x
Amazilia versicolor	G	Nec	Ge	3.4		x
Amazilia fimbriata	G	Nec	Ge	4.9	x	x
Trogoniformes						
Trogonidae						
Trogon viridis	F	Omn	S	89.3		x
Trogon rufus	F	Omn	U	52.5		x
Coraciiformes						
Momotidae						
Baryphthengus ruficapillus	F	Ins	M	145.5		x
Galbuliformes						
Galbulidae						
Galbula ruficauda	G	Ins	M	23	x	x
Piciformes						
Ramphastidae						
Ramphastos vitellinus	G	Fru	S	370		x
Picidae						
Picumnus cirratus	G	Ins	U	9.4	x	x

Colaptes campestris	OA	Ins	T	155	x	
Celeus flavescens	G	Ins	M	137.5	x	x
Falconiformes						
Falconidae						
Caracara plancus	OA	Car	T	1375		x
Milvago chimachima	OA	Car	T	335	x	
Micrastur semitorquatus	F	Car	Ge	723	x	
Psittaciformes						
Psittacidae						
Psittacara leucophthalmus	G	Fru	S	159		x
Pyrrhura frontalis	G	Fru	M	83		x
Amazona aestiva	G	Fru	S	400	x	
Passeriformes						
Thamnophilidae						
Myrmotherula axillaris	F	Ins	M	7.3	x	x
Myrmotherula unicolor	F	Ins	M	7.5		x
Thamnophilus palliatus	G	Ins	M	27	x	x
Drymophila squamata	F	Ins	U	10.8	x	
Xenopidae						
Xenops rutilans	F	Ins	M	12.5		x
Furnariinae						
Furnarius rufus	OA	Ins	T	48	x	
Philydor atricapillus	F	Ins	M	22		x
Phacellodomus rufifrons	OA	Ins	T	24.5	x	x
Certhiaxis cinnamomeus	OA	Ins	U	15	x	

Pipridae						
Manacus manacus	F	Fru	U	15	x	x
Chiroxiphia caudata	F	Fru	U	14.8		x
Tityridae						
Pachyramphus validus	G	Ins	S	43		x
Rhynchocyclidae						
Tolmomyias sulphurescens	G	Ins	S	14.9	x	x
Tolmomyias flaviventris	G	Ins	M	13.3	x	x
Todirostrum poliocephalum	G	Ins	M	7	x	x
Todirostrum cinereum	G	Ins	Ge	6.2	x	
Tyrannidae						
Hirundinea ferruginea	OA	Ins	Ge	34.4	x	x
Camptostoma obsoletum	G	Ins	M	8	x	x
Elaenia flavogaster	OA	Omn	S	21	x	x
Legatus leucophaius	G	Fru	S	22.5	x	x
Myiarchus tyrannulus	G	Ins	U	37	x	x
Pitangus sulphuratus	OA	Omn	Ge	53.8	x	x
Machetornis rixosa	OA	Ins	T	34.5		x
Myiodynastes maculatus	G	Omn	M	43.5	x	x
Megarynchus pitangua	G	Ins	S	61.5	x	x
Myiozetetes similis	G	Omn	M	25.5	x	x
Tyrannus melancholicus	OA	Ins	S	38.5	x	x
Tyrannus savana	OA	Ins	U	30.6	x	x
Empidonomus varius	OA	Ins	M	25	x	x
Fluvicola nengeta	OA	Ins	T	21	x	x

Lathrotriccus euleri	F	Ins	U	11.4		x
Xolmis velatus	OA	Ins	T	49.1	x	
Vireonidae						
Vireo olivaceus	G	Ins	S	18.6		x
Hirundinidae						
Pygochelidon cyanoleuca	OA	Ins	M	12	x	x
Stelgidopteryx ruficollis	OA	Ins	M	16	x	x
Troglodytidae						
Troglodytes musculus	OA	Ins	U	12	x	x
Cantorchilus longirostris	G	Ins	U	20.5	x	
Turdidae						
Turdus flavipes	G	Omn	Ge	63.5	x	x
Turdus leucomelas	G	Omn	Ge	62.5	x	x
Turdus rufiventris	G	Omn	Ge	75	x	x
Turdus amaurochalinus	G	Omn	Ge	62.5		x
Mimidae						
Mimus saturninus	OA	Omn	T	64	x	x
Motacillidae						
Anthus lutescens	OA	Ins	T	15.5	x	x
Passerellidae						
Ammodramus humeralis	OA	Gra	T	16	x	
Arremon semitorquatus	F	Fru	T	25		x
Parulidae						
Setophaga pitiayumi	G	Ins	S	6.9		x
Icteridae						

Cacicus haemorrhous	G	Omn	M	60.9	x	x
Gnorimopsar chopi	OA	Omn	T	71.8	x	x
Molothrus bonariensis	OA	Ins	T	55.7	x	
Thraupidae						
Tangara seledon	G	Omn	S	18.7	x	x
Tangara cyanocephala	G	Omn	S	18.8		x
Tangara sayaca	G	Omn	S	31	x	x
Tangara cyanoptera	G	Fru	S	43.5		x
Tangara palmarum	G	Omn	S	37.5	x	x
Tangara ornata	G	Fru	S	33		x
Tangara cayana	OA	Fru	Ge	18	x	x
Conirostrum speciosum	G	Omn	S	8.5	x	x
Sicalis flaveola	OA	Gra	T	17.7	x	x
Hemithraupis flavicollis	G	Ins	S	13		x
Volatinia jacarina	OA	Gra	T	10	x	
Lanio cristatus	G	Omn	S	18.8		x
Tachyphonus coronatus	G	Omn	Ge	29.5		x
Dacnis cayana	G	Omn	S	12.8	x	x
Coereba flaveola	G	Nec	Ge	10.3	x	x
Tiaris fuliginosus	OA	Gra	T	13.3	x	x
Sporophila lineola	OA	Gra	U	9.8	x	
Sporophila nigricollis	OA	Gra	U	9.9	x	
Sporophila caerulescens	OA	Gra	U	10	x	
Fringillidae						
Euphonia violacea	G	Fru	Ge	14.8	x	x

Euphonia xanthogaster	F	Fru	Ge	12.5	x	x
Euphonia pectoralis	F	Fru	S	15.8		x
Estrildidae						
Estrilda astrild	OA	Gra	T	8.5	x	