Research Article

Early bird assemblages under different subtropical forest restoration strategies in Brazil: passive, nucleation and high diversity plantation

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Abstract

Ecological restoration encourages management for the complexity and heterogeneity of habitats, which are crucial for avian fauna structure. Two-year-old bird assemblages were evaluated based on diversity parameters of three different ecological restoration technologies applied in southern Brazil: passive restoration (PR), nucleation (NC) and high diversity plantation (HD). Richness, abundance and diversity were compared using ANOVA factorial design (three treatments x four seasons, with six samplings per season). The highest richness was observed for NC (49 ± 2.45 SD species) and the lowest richness occurred in the HD treatment (37 ± 3.14 SD species), with a similar statistical pattern for abundance and diversity (NC>PR>HD). NC responded favorably to the hypotheses of dynamic equilibrium, heterogeneity and habitat complexity, which are the probable mechanisms that influence primarily assemblage richness. Due to the presence of exclusive species for each treatment, we recommend the application of a mix of the different techniques tested to maximize the number of habitats and their interactions with birdlife.

Keywords: neotropical forest, ecological restoration, avian fauna.

Resumo

A restauração ecológica estimula o manejo da complexidade e heterogeneidade de habitats, os quais são decisivos para a estruturação da avifauna. Foram avaliadas assembleia de aves com dois anos de idade segundo parâmetros de diversidade de três diferentes tecnologias de restauração ecológica aplicadas no sul do Brasil: restauração passiva (PR) nucleação (NC), e plantio de alta diversidade (HD). Os parâmetros de riqueza, abundância e diversidade foram comparados por meio de ANOVA em arranjo fatorial (três tratamentos x quatro estações com seis amostragens por estação). A maior riqueza observada foi constatada na NC (49 ± 2,45 espécies) e a menor riqueza ocorreu no tratamento PAD (37 ± 3,14 espécies) com um padrão estatístico semelhante para abundância e diversidade. NC respondeu favoravelmente às hipóteses do equilíbrio dinâmico, heterogeneidade e complexidade de habitats, sendo estes os prováveis mecanismos que influenciaram principalmente na riqueza da assembleia. Devido à presença de espécies exclusivas a cada um dos tratamentos, recomenda-se a aplicação conjunta das técnicas testadas para maximizar o número de habitats e suas interações com a avifauna.

Palavras chave: floresta neotropical, restauração ecológica, avifauna.

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Introduction

The increase in agricultural and urban areas is eliminating most of the tropical and subtropical forest remnants of the world [1, 2]. Deforestation influences global changes that affect biodiversity and causes alteration of the carbon cycle, increased erosion, and lack of connectivity between habitats [3]. There is therefore an urgent need to restore biotopes of terrestrial ecosystems [4, 5]. Many efforts are being made on a global scale to restore diverse environments to their natural, unaltered state [6, 7]. Determining the natural processes of revegetation is extremely important, because little is known about the complex interactions that maintain the stability of tropical and subtropical ecosystems [8], and the diversity of species [9, 10].

Restoration efficiency may be measured by the environmental value of species dependent on the quality of the vegetation, especially birds [10-12]. Birds are preferentially used to evaluate the effectiveness of restored areas because of their mobility, the speed at which they colonize new environments, their ability to connect habitats through seed dispersal, and their maintenance of gene flow among plant populations [13, 14].

Independent of the forest restoration technique, ecosystems restored under different procedures may gradually converge to form an ecosystem characteristic of the regional flora, due to the climax forest tendency [6, 13]. However, this is not such an obvious pattern, principally because of the stochasticity and randomness of environmental vectors, which tend to increase the floristic richness of the habitat [2, 13]. Nevertheless, the initial restoration plantings may be crucial to future successional processes [8, 17, 18].

Restoration using natural processes may be an important alternative, maintaining interdependence with the fauna and preserving the complex relationships in each phase of succession [18-19]. However, passive restoration is only possible in a highly resilient environment where natural vectors that promote seed dispersal are available nearby [16, 20].

Among the diverse active restoration techniques, tree planting is the most common and can provide great diversity and floristic richness over the long term [19, 21]. Nucleation techniques establish vegetation in small habitat patches, gradually restoring the environment and ecological relationships [22]. These techniques can offer extensive structural complexity through their own spatial configuration and insertion of structural elements into the landscape (*e.g.,* artificial perches, planting of seedlings in nuclei, etc.) [18, 20, 23]. According to Boanares and Azevedo [24], these techniques are more common in Brazil than in other countries, and all possible uses are as yet unknown. Based on the premise that complexity and heterogeneity directly affect the creation of niches, we tested different restoration techniques (nucleation, passive restoration and high diversity planting) and their effects on the richness, abundance and diversity of birds. In addition, we determined the bird assemblage structure and evaluated the degree of individual species' preferences for the experimental treatments.

Methods

Study area

The study was designed and conducted by F.C.B. on the experimental farm of the Universidade Tecnológica Federal do Paraná in the municipality of Dois Vizinhos, state of Paraná, Brazil (Fig. 1). The region was originally dominated by subtropical Atlantic Forest in the transition zone between the *Araucária* moist forest and seasonal semi-deciduous forest. The climate is *Cfa* (according to Köppen), with a mean temperature of 20 ^oC, at least one frost every two years, annual precipitation of about 2,000 mm, an altitude of nearly 500 m, and predominance of generally deep oxisols (Bw). The experimental area was historically used for agricultural purposes and pastures. In October 2010, during the last crop harvest of the year, the 7.2 ha experimental area was cleared using a tractor-mounted brush cutter to begin the treatment planting (restoration techniques) at the same time.

Experimental design

In a randomized block design, we tested four plot replications (40 x 54 m) of three treatments (each treatment totaling 0.86 ha): 1) passive restoration (PR); 2) nucleation (NC); and 3) high diversity planting (HD) (Fig. 1). A distance of 13±5 SD m (SD = standard deviation) was maintained between plots and 20.6±5.7 SD m from the nearby forest fragment.

The passive restoration (PR) treatment was also considered a control, and its plots, along with the plots of the other treatments, were protected against disturbances (fire, grazing, etc.).

In the nucleation (NC) plots, a set of seven techniques based on Reis et al. [18] was used (Fig. 2a) in six 3 x 40 m-strips occupying 1/3 of the total plot area. We used structural and functional techniques. For the structural sets we built: 1) six artificial shelters for fauna (1 m^3-woodpile); 2) two artificial perches (10 m high) made of *Eucalyptus* poles (including dried crowns and cultivating native climber Sweet-passion-fruit, *Passiflora alata*). The functional sets consisted of: 3) six 1 m^2-topsoil seed bank sod blocks (topsoil collected from a nearby secondary forest remnant - 25^{o}36'83" S; 53^{o}04'10" W - and deposited in trays to cultivate regenerating seedlings, which were planted in the field as sod blocks); 4) six 1-m^2 seed rain sod blocks (seed rain was collected in thirty 1 m^2-seed traps in the same nearby forest remnant, and like the seed bank, sowed in trays to cultivate regenerating seedlings, which were planted in the field as sod blocks); 5) Cover-crop of Pigeon pea (*Cajanus cajan*) was sown in twelve 3 x 4 m-nuclei; 6) six bromeliad (*Bromelia antiacantha*) islets were planted (five seedlings 0.5 m apart in a "+" shape); and lastly, 7) 24 native tree islets composed of five seedlings planted 1 m apart in a "+" shape formed by four rapid-growth pioneer seedlings at the edges and a shaded non-pioneer species in the center (we used 556 seedlings.ha^{-1}, 12 pioneer species and 24 non-pioneer, listed in Appendix 1).

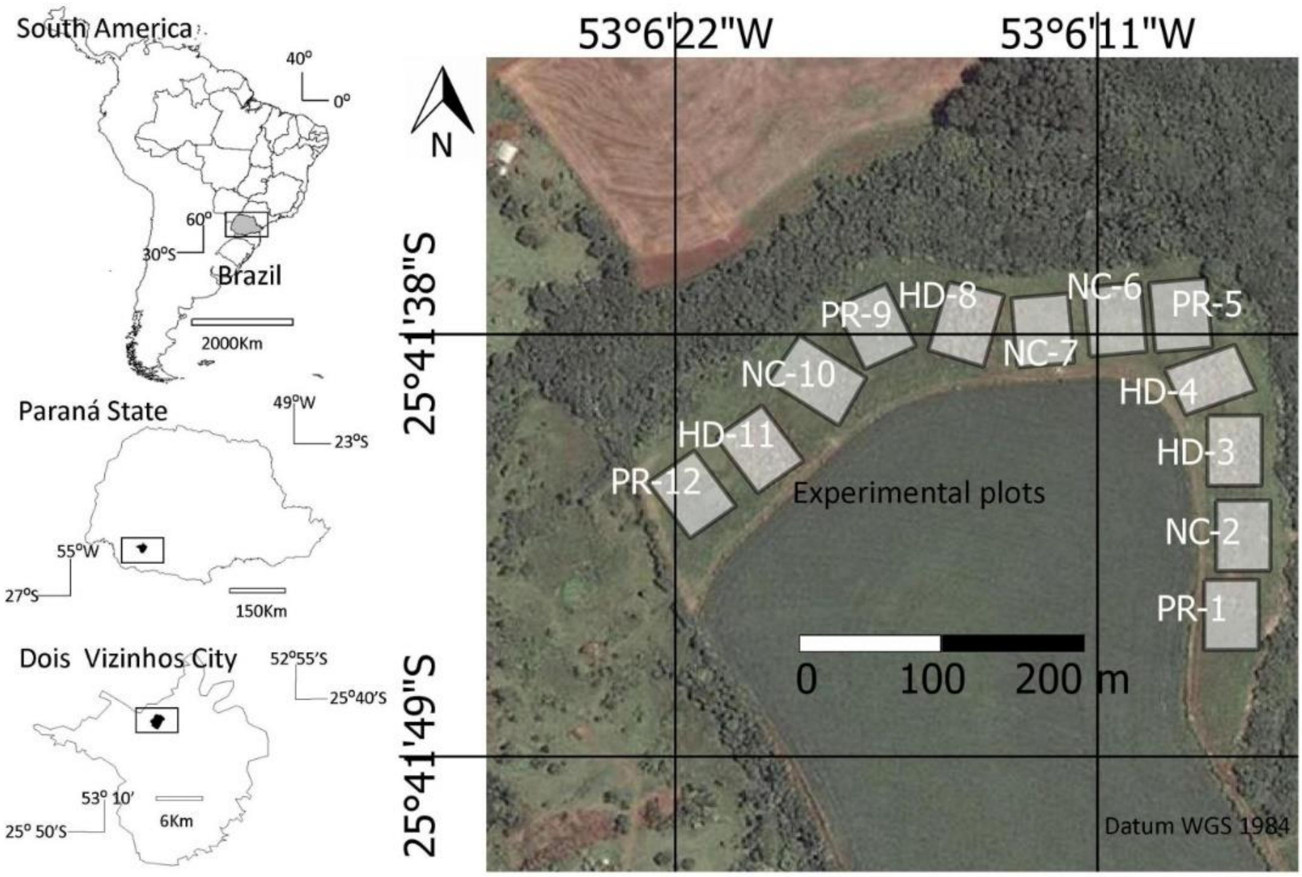

Fig. 1: Map indicating the location of the study area and arrangement of experimental plots: nucleation (NC), passive restoration (PR) and high diversity plantation (HD).

The high diversity plantation (HD) design was based on the Brazilian filling and diversity lines technique [17, 25-26], where a total of 70 native tree species were planted (10 fast-shading filling species interspersed within the lines of 60 non-pioneer shaded species, listed in the Appendix 1 supplementary document) in a 3 x 2 m-spacing (Fig. 2b). NC and HD were mowed twice a year using a portable brush cutter, followed by the application of glyphosate (2.5 kg of Roundup WG©. ha^{-1} applied using a hand sprayer in dry, non-windy conditions, excluding drift between plots) for weed control, throughout the duration of the study. The mowing and subsequent herbicide application was done each time in the entire area of the HD plots, and just inside the NC area occupied by the six 3 x 40 m-strips. PR received no herbicide, and the herbicide's environmental impacts were not evaluated here.

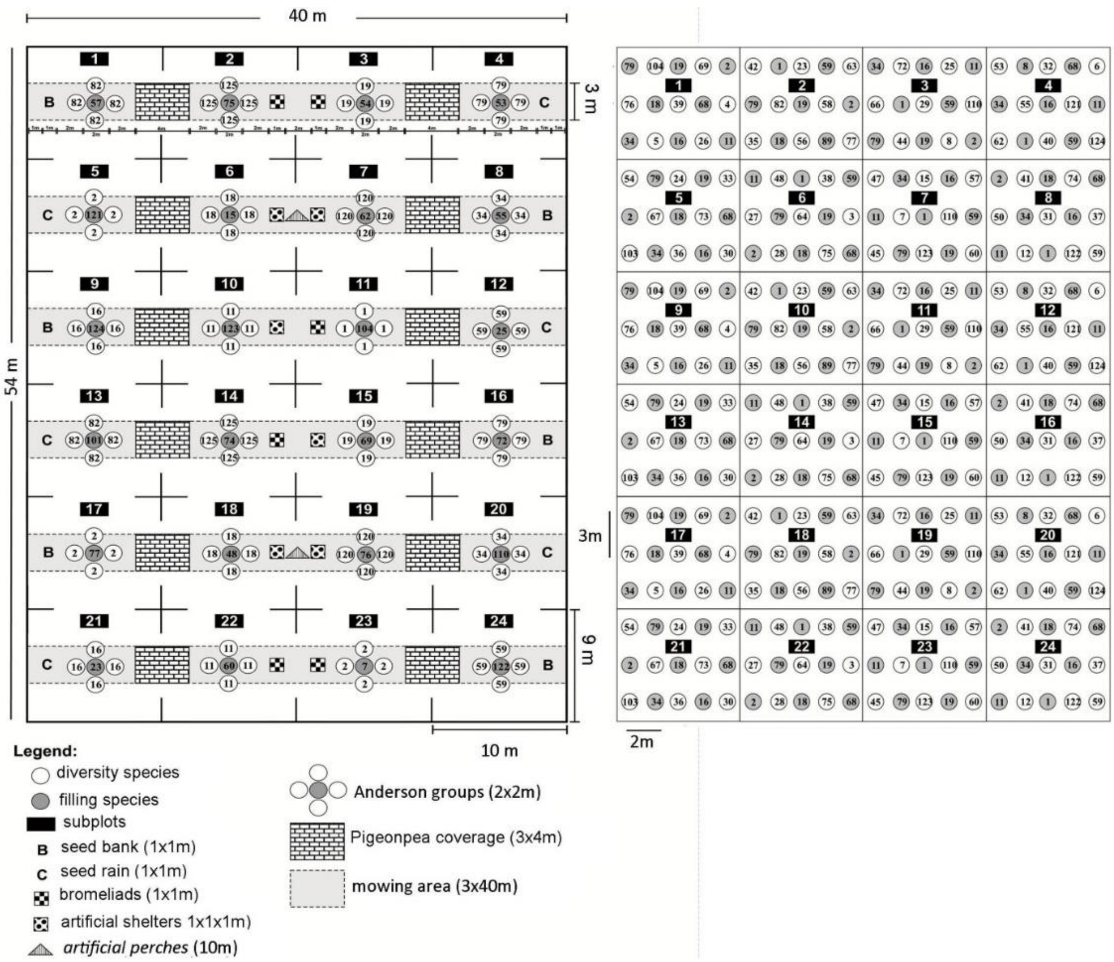

Fig. 2: Nucleation (a) and high diversity plantation (b) designs made by F.C.B. The numbers correspond to the species described in the supplementary document (Appendix 1).

Data collection

There were 24 samplings (six per season), with a sampling effort of eight hours per plot or 96 hours during the entire experiment, between January and December 2012. A bird census was carried out one year after the beginning of the restoration. The species were recorded only when they occurred within the limits of the plots (*e.g.,* on their perches, on the ground or on shrubs). They were recorded in flight when foraging at a height lower than the artificial perches. We obtained estimates of richness and abundance using straight counting of a single sampling point in the center of each experimental plot, with observers' movements allowed to obtain a visual record of the species [27]. The samplings occurred every fifteen days; however, some observations were delayed by meteorological events (*e.g.,* rain and wind), so that the samplings were standardized on sunny days or days with light rain (< 5 mm). Each sampling lasted 20 minutes (10 in the morning and 10 in the afternoon). The beginning of the census occurred when the sun was at an angle of approximately 5° on the horizon, and in the afternoon at 45°. This arrangement was chosen because 20 consecutive minutes would greatly increase the chance of resampling the same individuals. Dividing the 20 minutes into two 10-minute periods may lead to an overestimation of abundance, but it increases the chance of detecting discrete species [28]. However, abundance should be interpreted with caution due to a bias caused by differences in detectability of species. Even so, it is a relevant metric for comparisons between plots. The nomenclature used to identify the birds is according to the Brazilian Committee of Ornithological Records of 2014.

Data analysis

We did the Shapiro-Wilk test (for normality) and the Bartlett test (for homogeneity of the variances) to explore the data [29]. In addition to richness (S) and abundance (N), diversity was obtained by means of the Shannon-Weaver (H') index and Pielou estimating for uniformity ($e^{H/S}$), according to Krebs [30]. Berger-Parker dominance (D) was estimated for the total of contacts between treatments, with later ordination, using the Whittaker diagram [31]. Based on the rank of dominance (D), the use of the scree test was adapted [32]. This test was used as a criterion to determine which species possess greater representativeness in abundance for each treatment. The mean values per sampling of the parameters of richness, abundance and diversity were subjected to an analysis of variance (ANOVA) factorial design (three treatments x four seasons with six samplings per season). A post hoc Tukey test was carried out next.

Rarefaction curves were carried out for observed richness of both the samplings and the abundance of the individuals, using the software EstimateS® v.8.2. [http://viceroy.eeb.uconn.edu/stimates]. Additionally, richness estimates, richness estimates were obtained (estimators Chao 2 and Jacknife 1) using the procedure of 10,000 randomizations, which are indicated for situations in which the sampled populations are composed of several unidentified subpopulations [33].

The total abundance data (sum of the 24 samplings) in the 12 restored plots were grouped (Bray-Curtis coefficient) through the UPGMA (Unweighted Pair Group Method with Arithmetic Mean) in order to show the patterns of similarity in the species composition. The UPGMA was chosen to minimize the distortion of the initial matrix of similarity in the construction of the dendrogram without a defined cutting height, prioritizing natural groupings. The Bray-Curtis coefficient was used because it was considered the most efficient to carry out the analysis of similarity (ANOSIM), using 10,000 permutations and comparing the similarity among the treatments to the *post hoc* test of pairwise comparisons of Mann-Whitney [34].

In order to evaluate the possibility of individual species' preferences for the treatments [35] we used a species indicator analysis (IndVal). This method combines the degree of specificity of a species to the habitat (in this case, different treatments) and its fidelity, assuming two or more groups established *a priori* [36]. The indicator index (IV) was obtained for each species (the group with the highest association value was identified). A total of 10,000 permutations were carried out again to test the significance of the values through the Monte-Carlo statistic ($\alpha<0.05$).

The species were classified according to preferential habitat, based on Ries and Sisk [37] and Scherer-Neto and Toledo [38]: 1) open areas (OA) - species that occur in agricultural areas, abandoned fields, pastures; 2) forest (FO) - species that occur in canopy and understory); and 3) edges (ED) - species common to the margin of the forest, with little sensitivity to the edge effect and tolerant of small gaps. Birds were classified in trophic groups, based on Cueto and Casanave [39] and Telino-Júnior et al. [40], according to the predominant feeding (omnivores, nectarivores, insectivores, granivores, frugivores and carnivores). For the status of their occurrence, based on Cueto and Casanave [39] and Bencke [41], we classified: 1) migrants (M); and 2) residents (R). The frequency of occurrence index [42] was based on the nomenclature used by Lack and Venables [43]: 1) very abundant (80 ⊦ 100%); 2) abundant (60 ⊦ 80%); 3) frequent (40 ⊦ 60%); 4) occasional (20 ⊦ 40%); 5) rare (1 ⊦ 20%); and 6) very rare (< 1%). Species abundance was based on Berger-Parker dominance, by grouping in classes of dominance, according to Palissa et al. [44]: 1) eudominant (> 10%); 2) dominant (10 ⊦ 5%); 3) subdominant (2 ⊦ 5%); 4) recessive (1 ⊦ 2%); 5) rare (< 1%). The proportions of species in the categories of preferential habitat, trophic groups, status of occurrence, frequency of occurrence, and frequency of dominance were compared among treatments and categories through the chi-square (χ^2) test, with the null hypothesis of equality ($\alpha=0.05$) using the Yates correction [45].

Results

A total of 58 species were recorded, and 48.28% (n = 28) were present in all treatments. The birds were grouped in 22 families: Thraupidae (n = 14; 24.14%) and Tyrannidae (n = 10; 17.25%) were the most representative (Appendix 2). The highest richness was verified for the NC treatment ($S_{obs.}$ = 49 ± 2.45 species) and the lowest in HD ($S_{obs.}$ = 37 ± 3.14 species). The comparison between the mean richness presented a high value of statistical divergence ($F_{[2; 276]}$ = 61.79; P < 0.01). Abundance and diversity were also superior in the group of nucleation techniques (NC > PR > HD). The Tukey test indicated that the PR treatment at all times assumed intermediate values between NC and HD (Tables 1-2). Seasonality had an influence because higher means of the studied parameters always occurred in the summer and in the spring (Table 1 and Fig. 3a-c).

Based on the ordination of dominance (Fig. 3d), the scree test indicated the selection of four species that, together, represented 60% of the total of records in the NC treatment: Blue-black

Grassquit (*Volatinia jacarina*, D=16%), Red-crested Finch (*Lanio cucullatus*, D=16%), Double-collared Seedeater (*Sporophila caerulescens*, D=15%) and Ruddy Ground-dove (*Columbina talpacoti*, D=12%). In PR, according to the criteria of ranking, the three most abundant species were selected (62% of the total): Blue-black Grassquit (D=24%), Red-crested Finch (21%) and Double-collared Seedeater (17%). In HD, three species were also selected (47% of the total): Red-crested Finch (D=19%), Ruddy Ground-dove (15%) and White-tipped Dove (*Leptotila verreauxi*, 13%). Exclusively in the NC treatment were: White-tailed Kite (*Elanus leucurus*), Yellow-headed Caracara (*Milvago chimachima*), Picazuro pigeon (*Patagioenas picazuro*), Boat-billed Flycatcher (*Megarynchus pitangua*), Variegated Flycatcher (*Empidonomus varius*), Grassland Sparrow (*Ammodramus humeralis*), Swallow Tanager (*Tersina viridis*), and Bay-winged Cowbird (*Agelaioides badius*). Planalto Hermit (*Phaethornis pretrei*), Ochre-collared Piculet (*Picumnus temminckii*), Yellow-browed Tyrant (*Satrapa icterophrys*), Black-goggled Tanager (*Lanio melanops*) and Yellow-bellied Seedeater (*Sporophila nigricollis*) occurred only in PR. Burrowing Owl (*Athene cunicularia*), Slaty-Breasted Wood-rail (*Aramides saracura*), and Pauraque (*Hydropsalis albicollis*) were exclusive to HD.

By means of rarefactions, the highest observed richness occurred in NC (Fig. 3e and f). The estimated richness was also superior in NC [50.38 ± 3.50 species (SD), through Jacknife 1; and 48.14 ± 5.45 species (SD), using Chao 2]. The values were always higher than the observed for the estimator Jacknife 1, with lower estimates for the estimator Chao 2. The graphic analysis of the accumulation curves allows the inference that a satisfactory asymptote of richness was not observed in any of the treatments.

Table 1. Descriptive statistics and results of the factorial variance analysis for the parameters richness, abundance and diversity between nucleation (NC), passive restoration (PR) and high diversity plantation (HD). Legend: MS = mean square; F = value of the ANOVA test; P = value of probability (95%); SD = standard deviation. Means followed by the same letter do not differ through the Tukey test (95%).

Parameters	Variation source	DF	MS	F	P	Treatments	Mean	SD
Richness (S)	Treatments	2	410.45	83.68	0.00	NC	6.83 **(a)**	0.23
	Seasons	3	97.06	19.79	0.00	PR	4.78 **(b)**	2.60
	Interaction	6	7.17	1.46	0.19	HD	2.70 **(c)**	1.97
	Error	276	4.90	-	-	-	-	-
Abundance (N)	Treatments	2	3292.30	50.25	0.00	NC	16.48 **(a)**	0.83
	Seasons	3	727.07	11.10	0.00	PR	11.43 **(b)**	11.01
	Interaction	6	82.66	1.26	0.28	HD	4.80 **(c)**	4.42
	Error	276	65.51	-	-	-	-	-
Diversity (H')	Treatments	2	18.79	78.40	0.00	NC	1.63 **(a)**	0.46
	Seasons	3	4.37	18.22	0.00	PR	1.24 **(b)**	0.51
	Interaction	6	0.36	1.51	0.17	HD	0.75 **(c)**	0.61
	Error	276	0.24	-	-	-	-	-

Table 2. Descriptive statistics and Tukey test to compare the parameters richness (S), abundance (N) and diversity (H') between seasons based on general means of the treatments. Means followed by the same letter do not differ through the Tukey test (95%).

Seasons	Mean	S	S	Mean	N	N	Mean	H'	H'
		-95%	95%		-95%	95%		-95%	95%
Summer	5.65 a	5.00	6.30	13.96 a	11.77	16.14	1.36 a	1.21	1.50
Autumn	3.68 b	3.03	4.33	8.79 b	6.61	10.98	0.94 b	0.80	1.08
Winter	3.86 b	3.21	4.51	7.60 b	5.41	9.78	1.06 b	0.91	1.20
Spring	5.89 a	5.24	6.54	13.26 a	11.08	15.45	1.47 a	1.32	1.61

Evenness (J') was more stable over the samplings in NC [J' = 0.87 ± 0.06 species (SD)], with a coefficient of variation of 6.84%, very similar to the pattern observed in PR [J' = 0.84 ± 0.08 species (SD)], with a coefficient of variation of 9.64%. However, the fluctuation of the evenness in HD was highly variable, reaching a mean of J' = 0.63 ± 0.27 species (SD), with a coefficient of variation reaching 43.10% (Fig. 3g).

The similarity analysis among plots pointed to the formation of two distinct groups [(ANOSIM), R = 0.51; P < 0.01]. One of the formed groups contained restored plots with applied nucleation and passive restoration. Plots restored on high diversity plantations formed an external group, distinct from the other treatments (Fig. 2h).

IndVal analysis allowed the selection of 10 indicator species, with only one, the Striped Cuckoo (*Tapera naevia,* IV=75) in the PR treatment, while another nine species were associated with NC: Ruddy Ground-dove (IV=59.5), Smooth-billed Ani (*Crotophaga ani*, IV=61.7), Shiny Cowbird (*Molothrus bonariensis*, IV=80), Great Kiskadee (*Pitangus sulphuratus*, IV=67), Roadside Hawk (*Rupornis magnirostris*, IV=80), Fork-tailed Flycatcher (*Tyrannus savana*, IV=85), Tropical Kingbird (*Tyrannus melancholicus*, IV=65), Eared Dove (*Zenaida auriculata*, IV=73.3) and Yellow-bellied Elaenia (*Elaenia flavogaster*, IV=75). Seven species were considered migratory (12%). This pattern was maintained among treatments (Table 2).

There was a predominance of 57% of species characteristic of open areas (n = 33), while the characteristics of edges and forest environments (n = 14 and 11, respectively) completed the sampling total. Variations in the quantity of species among the different classes of preferential habitats in the same treatment were detected by means of the χ^2 test; however, no variations were verified in the proportions within each class among treatments (Appendix 3). A predominance of species characterized as rare occurred in all treatments (NC: χ^2 = 40.76, df = 5, P < 0.01; PR: χ^2 = 47.63, df = 5, P = 0.00; HD: χ^2 = 67.94, df = 5, P < 0.01). There was a variation between treatments only in the class of frequent species, with 10 species in NC (χ^2 = 8.78, df = 2, P < 0.05). Other classes were constant (Appendix 3).

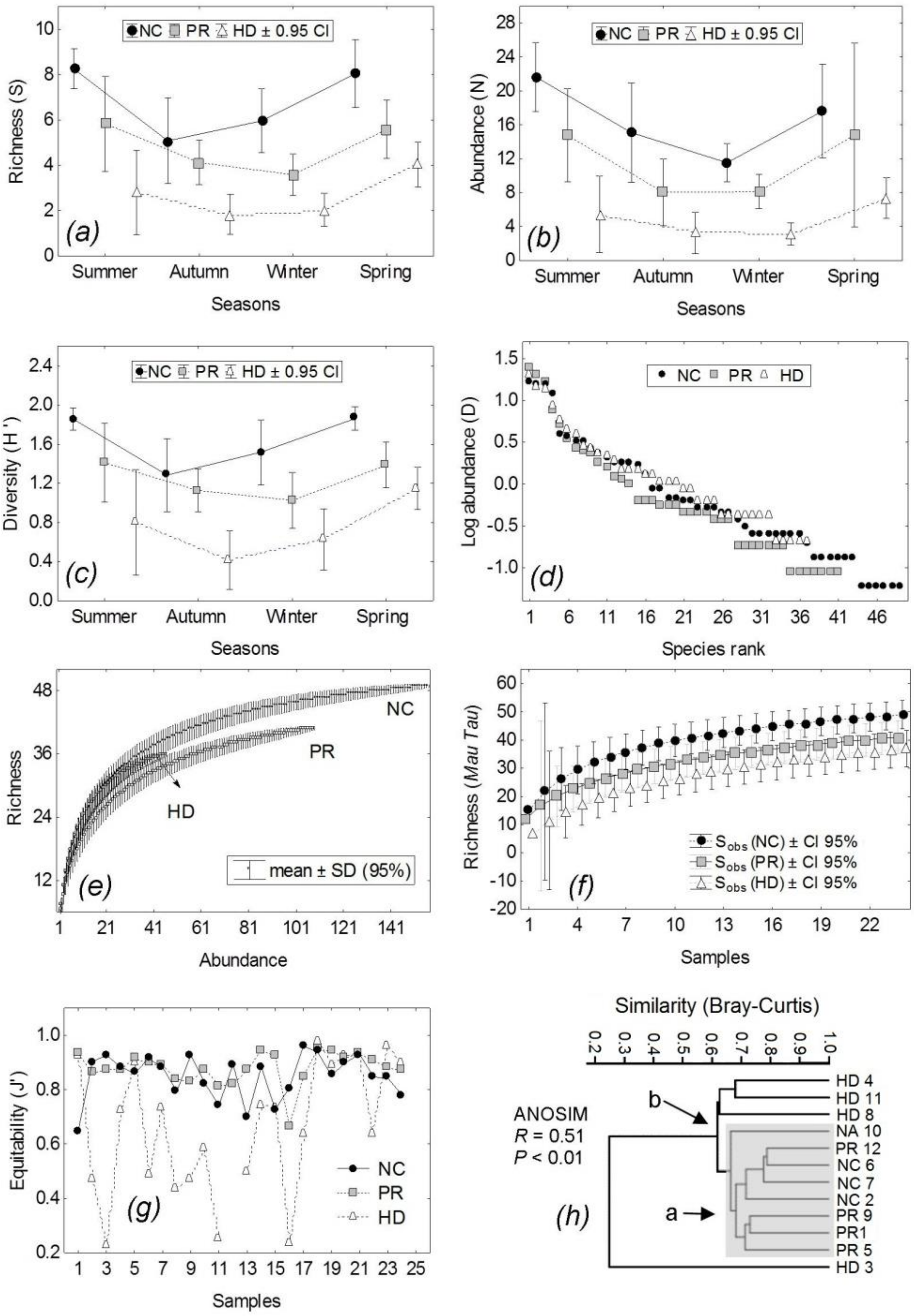

Fig. 3: Graphic representations over the seasons and samplings in relation to the parameters: (a) mean richness - S; (b) mean abundance - N; (c) mean diversity - H'; (d) ordination of Berger-Parker dominance represented by the Whittaker diagram; (e) rarefaction of the observed richness as regards abundance; (f) rarefaction curves of the richness as regards the samplings (Mao Tau); (g) annual fluctuation of uniformity - J'; and (h) dendrogram of similarity (Bray-Curtis) between experimental plots, with ordination through the UPGMA.

Discussion

Within 58 bird species recorded, the families Thraupidae and Tyrannidae represented 41% of the richness. These families are characteristic of open, altered, or disturbed environments, common in areas in the early stage of ecological succession, and are also the most abundant in forest habitats in the Neotropical region [46-47]. The elevated species richness of the family Tyrannidae is directly related to the variation observed in the seasonality, because this group corresponds to one third of the austral migrants [48], with preference for open areas [49]. The seasonal variation found for the parameters of diversity has practical implications for ecological restoration, as some studies have indicated a direct relationship between the presence of migratory species and a seasonal increase in the deposition of seeds dispersed by birds [50-51].

Tyrannidae species found in this work are considered by many authors to be insectivores or omnivores (generalists), efficiently dispersing seeds by removing them from canopies and edges and depositing them in viable conditions along open landscapes [52-53]. This ecosystemic function is very important for ecological restoration, as specialized frugivores generally occur in low density or do not occur at all in altered landscapes [9, 13, 54].

The pattern observed for richness, diversity and abundance follows a gradient (NC > PR > HD), corroborating the hypothesis that higher levels of complexity and heterogeneity in NC can increase richness, which influences diversity and abundance (dependent parameters). In summary, studies that link bird assemblages to environmental factors find direct relationships between increase in the structural complexity and increase in the diversity of birds [12, 55, 56].

Dominance analysis demonstrated that only five species represent 47% in HD and up to 60% in NC: Blue-black Grassquit, Red-crested Finch*,* Double-collared Seedeater*,* Ruddy Ground-dove and White-tipped Dove. Except for White-tipped Dove, these species commonly occur in open areas [57]. They are ruderal and granivorous and adapt well to environments in early stages of succession [58].

A total of 78% of the species occurring in HD were characteristic of open areas or on the edges. The composition of the assemblage composed of generalist species affected the avian fauna analysis of similarity, where the HD plots recorded a pattern that was different from NC and PR. According to Munro et al. [11], the richness of the avian fauna in forest habitats actively restored by different techniques can be similar, but the faunal composition can be different, with a predominance of more generalist species in large scale plantations. On the other hand, species of forest birds are more associated with plantations that have undergone minor interventions [59, 60].

The occurrence of Ruddy Ground-dove and White-tipped Dove among the higher dominance species in HD and NC treatments is due to the biology of the species themselves, since they benefit from the mowing and chemical weeding of the clearing management procedures (bare soil is the predominant habitat where Columbiformes obtain small fallen fruits and seeds [61, 62]). These data demonstrate that the preference for a certain procedure may involve biological and ecological characteristics of the species, as discussed by Báldi and Batári [63], who pointed out that grassland birds may be benefited by the homogenization of the environment. Specialization by a certain stage of the ecological succession process was observed, corroborating Sanderson et al. [56], who demonstrated the relationship between the decrease in the pioneer vegetation and the decline of some bird populations.

Evenness in HD was more variable. Theoretically, lower levels of evenness are caused by assemblages of a smaller number of species (but with high dominance, common in unstable environments) [9]. Instability in early-restoration habitats can be strongly favored by the edge effect, which is a result of management of the vegetation, as well as environments in the initial stages of ecological succession with variations in environmental conditions (*e.g.,* luminosity and humidity) [15, 17], which restrict the availability of resources for birds [64].This tendency might be reversed with the growth of the vegetation over the ecological succession [2, 6], but these first two years of monitoring are not sufficiently conclusive to determine the importance of HD in the maintenance of bird diversity.

Articles about the persistence of birds in restored landscapes demonstrate alteration in the community over the ecological succession [14, 56]. This tendency is reinforced by the accumulation curves obtained in this paper, showing that the process of succession and arrival of new colonizers is in full swing. It is important to emphasize that in the dynamics of colonization, in some situations the bird assemblage converges rapidly to a structure similar to that of nearby forest fragments [65]. On other occasions the structure of the avian fauna may take different directions, with species adapted to the structure of the vegetation [12, 66], generally influenced by the distance between forest fragments or by the change in the structure of the vegetation [23, 67].

IndVal analysis demonstrated the preference of nine species for the NC treatment, which when added to the exclusive species, totaled 17 birds (29.3%) that have preferences for different nucleation strategies and management intensities. However, generalizations should be avoided, since some species had few records, while others had a low value of association.

We recorded Ochre-collared Piculet and Yellow-browed Tyrant exclusive to PR. Despite occupying distinct niches, they are predominantly insectivores, a guild shared with Striped Cuckoo [68, 69], which was associated with PR in the IndVal test. Although insectivore richness was the same between NC and PR, the specific composition was different.

Exclusive to HD, Burrowing Owl, Slaty-breasted Wood-rail, and Pauraque have a high tolerance to habitat disturbances and forage in open environments. Burrowing Owl is carnivorous and insectivorous, while Pauraque is insectivorous in open areas. Both are nocturnal [70, 71]. Although the richness of forest species is also similar among the treatments, these species have low sensitivity to habitat disturbance [72] and are probably not good indicators in early succession.

The analysis of the frequency of occurrence demonstrated variations in the category of frequent species (between 40 and 60% of the samples), with a higher quantity in NC. This observation suggests that the habitat supplies resources in a more constant way [73, 74], conferring an important role in the local maintenance of the avifauna.

NC responded sufficiently well to richness, abundance, and diversity. The intermediate vegetation management in NC can be an important variable to be measured in later studies, because it causes less intense disturbance than HD. Increased functional heterogeneity in NC is possibly promoted through modification of the spatial and temporal variability of the resources [75-76]. On the other hand, increasing the structural complexity of the habitat, as well as the spatial arrangement of the techniques used in the NC restoration, allows a rapid increase in available niches, which is controlled by the availability of structural resources [77-78]. Thus, the use of perches, tree islets, and shelters for the fauna, and the recurring exposure of part of the soil, can bring about a larger number of environmental niches, and therefore, more species could benefit, discretely increasing richness and diversity in habitats restored under nucleation. However, monitoring of the three treatments should be continued, to evaluate whether with time, the tendency verified in NC will be maintained or the other methods increase in their ecosystemic value [21, 79].

Implications for conservation

Nucleation techniques presented higher richness, abundance and diversity of birds than the passive and plantation techniques during the first two years of ecological succession. We suggest that both restoration methods responded favorably to the habitat complexity hypotheses and to the dynamic equilibrium hypothesis, and are the probable mechanisms for increasing richness and controlling the diversity of bird species in ecosystems under ecological restoration. In order to guarantee the largest number of niches for birds in restoration, we recommend a mix of the three technologies tested, combined in the same space and time, since each one presented exclusive species and because some bird species still lack studies about their ecological behavior.

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APPENDIX 1

List of species planted in high diversity plantation (HD) and nucleation (NC). The nomenclature adopted for families and genera follow the Angiosperm Philogeneny Group III [86]. Species identification (epithets) follows the List of Flora of Brazil -2013 [http://floradobrasil.jbrj.gov.br] and The International Plant Names Index – 2013 [http://www.ipni.org]. The period of fructification and dispersal syndrome were based on specific literature [80-88]. Silvicultural groups, where "filling" is fast-shading pioneer trees; and "diversity" is non-pioneer trees.

Code	Family	Species	Fruiting season	Seed dispersal ways	Silvicultural group
1	Euphorbiaceae	*Croton floribundus* Spreng.	summer/autumn	autocory	filling
2	Fabaceae	*Mimosa scabrella* Benth.	summer/autumn	autocory	filling
3	Primulaceae	*Myrsine coriaceae* (Sw.) R. Br	spring/summer	zoochory	diversity
4	Myrtaceae	*Psidium cattleyanum* (Mart. ex O. Berg) Kiaersk.	spring/summer	zoochory	diversity
5	Phytolaccaceae	*Gallesia integrifolia* (Spreng.) Harms	winter/spring	anemochory	diversity
6	Myrtaceae	*Myrcianthes pungens* (O.Berg) D.Legrand	spring/summer	zoochory	diversity
7	Aquifoliaceae	*Ilex paraguariensis* A.St.-Hil.	summer/autumn	zoochory	diversity
8	Laminaceae	*Vitex megapotamica* (Spreng.) Moldenke	spring/summer	zoochory	diversity
11	Cannabaceae	*Trema micrantha* (L.) Blume	summer	zoochory	filling
12	Annonaceae	*Annona cacans* Warm.	summer/autumn	zoochory	diversity
15	Caricaceae	*Jaracatia spinosa* (Aubl.) DC.	summer	zoochory	diversity
16	Euphorbiaceae	cf. *Croton urucurana* Baill.	summer/autumn	autocory	diversity
18	Sterculiaceae	*Guazuma ulmifol*ia Lam.	autumn/winter	zoochory	filling
19	Fabaceae	*Piptadenia gonoacantha* (Mart.) J.F. Macbr.	spring	autocory	filling
23	Loganiaceae	*Strychnos brasiliensis* (Spreng.) Mart.	spring/summer	zoochory	diversity
24	Fabaceae	*Machaerium stipitatum* (DC.) Vogel	autumn	anemochory	diversity
25	Rosaceae	*Prunus myrtifolia* (L.) Urb.	summer	zoochory	diversity
26	Rubiaceae	*Randia ferox* (Cham. & Schltdl.) DC.	winter/spring	zoochory	diversity

27	Sapindaceae	*Allophyllus edulis* (A.St.-Hil., Cambess. & A. Juss.) Radlk.	spring/summer	zoochory	diversity
28	Fabaceae	*Cassia leptophylla* Vogel.	autumn winter	autocory	diversity
29	Lauraceae	*Ocotea porosa* (Nees) Barroso	spring/summer	anemocoric	diversity
30	Elaeocarpaceae	*Sloanea monosperma* Vell.	spring/summer	autocory	diversity
31	Cannabaceae	*Celtis iguanaea* (Jacq.) Sargent	winter/spring	zoochory	diversity
32	Lythraceae	*Lafoensia pacari* A.St.-Hil	autono/winter	anemochory/autocory	diversity
33	Primulaceae	*Myrsine umbellata* Mart.	summer	anemocoric	diversity
34	Euphorbiaceae	*Alchornea triplinervia* (Spreng.).	summer	zoochory	filling
35	Myrtaceae	*Campomanesia xanthocarpa* O.Berg	spring/summer	zoochory	diversity
36	Fabaceae	*Inga vera* Willd.	spring/summer	zoochory	diversity
37	Bignoniaceae	*Jacaranda micrantha* Cham.	spring/summer	zoochory	diversity
38	Asteraceae	*Moquiniastrum polymorpha* (Less.) Cabr.	spring/summer	anemochory	diversity
39	Meliaceae	*Cabralea canjarana* (Vell) Mart	winter/spring	zoochory	diversity
40	Lauraceae	*Ocotea puberula* (Rich.) Ness	spring/summer	zoochory	diversity
41	Fabaceae	*Calliandra tweedii* Benth.	summer/autumn	autocory	diversity
42	Podocarpaceae	*Podocarpus lambertii* Klotzsch	summer/autumn	zoochory	diversity
44	Canellaceae	*Cinnamodendron dinisii* Schwacke	summer	zoochory	diversity
45	Salicaceae	*Xylosma* sp.	spring/summer	zoochory	diversity
47	Euphorbiaceae	*Sebastiania commersoniana* (Baill.) L.B. Sm. & Downs	spring/summer	autocory	diversity
48	Boraginaceae	*Cordia americana* (L.) Gottshling & J.E.Mill.	spring/summer	anemochory	diversity
50	Euphorbiaceae	*Sebastiania schottiana* (Müll.Arg.) Müll.Arg.	spring/summer	autocory	diversity
53	Myrtaceae	*Campomanesia guazumifolia* (Cambess.) O.Berg.	spring/summer	zoochory	diversity
54	Sapindaceae	*Cupania vernalis* Cambess.	summer	zoochory	diversity
55	Meliaceae	*Cedrela fissilis* Vellozo	spring/summer	anemochory	diversity
56	Malvaceae	*Ceiba speciosa* (A. St.-Hil.) Ravenna	summer	anemochory	diversity
57	Bignoniaceae	*Handroanthus chrysotrichus* (Mart. ex A.DC.) Mattos	spring/summer	anemochory	diversity
58	Rutaceae	*Zanthoxylum rhoifolium* Lam.	summer	zoochory	diversity
58	Rutaceae	*Balfourodendron riedelianum* (Engl.) Engl.	summer	anemochory	diversity
59	Anacardiaceae	*Schinus terebinthifolius* Raddi	summer/autumn	zoochory	filling
60	Moraceae	*Ficus enormis* (Mart. ex Miq.) Mart.	autumn/winter	zoochory	diversity
63	Fabaceae	*Peltophorum dubium* (Spreng.) Taub.	summer	autocory	diversity

64	Fabaceae	*Lonchocarpus* sp.	--	autocory	diversity
66	Sapindaceae	*Diatenopteryx sorbifolia* Radlk.	spring/summer	anemochory	diversity
67	Fabaceae	*Erythrina falcata* Benth.	spring/summer	autocory	diversity
68	Fabaceae	*Bauhinia forficata* Link	summer	autocory	filling
69	Salicaceae	*Casearia decandra* Jacq.	summer	zoochory	diversity
72	Meliaceae	*Trichilia claussenii* C. DC.	summer	zoochory	diversity
73	Myrtaceae	*Myrceugenia euosma* (O.Berg) D. Legrand	spring/summer	zoochory	diversity
74	Myrtaceae	*Eugenia pyriformis* Cambess.	summer/autumn	zoochory	diversity
75	Myrtaceae	*Eugenia uniflora* L.	summer/autumn	zoochory	diversity
76	Myrtaceae	*Eugenia involucrata* DC.	summer/autumn	zoochory	diversity
77	Myrtaceae	*Plinia peruviana* (Poir.) Govaerts	summer	zoochory	diversity
79	Solanaceae	*Solanum bullatum* Vell.	summer	zoochory	filling
101	Apocynaceae	*Aspidosperma polyneuron* Müll.Arg.	winter/spring	anemocorica	diversity
103	Fabaceae	*Albizia polycephala* (Benth.) Killip	summer	anemochory	diversity
104	Araucariaceae	*Araucaria angustifolia* (Bertol.) Kuntze	autumn/winter	zoochory	diversity
110	Fabaceae	*Parapiptadenia rigida* (Benth.) Brenan	spring/summer	autocory	diversity
120	Fabaceae	*Mimosa bimucronata* (DC.) Kuntze	summer/autumn	autocory	diversity
121	Arecaceae	*Butia capitata* (Mart.) Becc.	autumn	zoochory	diversity
122	Celastraceae	*Maytenus aquifolia* Mart.	spring/summer	zoochory	diversity
123	Polygonaceae	*Ruprechtia laxiflora* Meisn.	summer	anemocoric	diversity
124	Arecaceae	*Syagrus romanzoffiana* (Cham.) Glassman	summer/autumn	zoochory	diversity
125	Fabaceae	*Enterolobium contortisiliquum* (Vell.) Morong	autumn	zoochory	filling

APPENDIX 2

List of species (Brazilian Committee of Ornithological Records of 2014) for birds occurring in nucleation (NC), passive restoration (PR) and high diversity plantation (HD). The code (*D*) represents the main diet of the species: C = carnivorous, F = frugivorous, G = granivorous, I = insectivorous, N = nectarivorous and O = omnivorous. The code (*H*) corresponds to the preferential habitat of the species (Oa = open areas; Ed = forest edges and Fr = forests). The code (*S*) represents status of occurrence (R = resident and M = migratory). The abbreviations *fo%* and *fd%* correspond, respectively, to frequency of occurrence and frequency of dominance in percentage. For IndVal (*indicator species analysis*), the value of the indicator (IV) is presented, followed by the standard deviation. (*) level of statistical acceptance at 5% of probability ($P < 0.05$) and (**) the level of 1% of probability of the Monte Carlo test for the association between treatments (groups). SD = standard deviation.

Species	Code			NC		PR		HD		IndVal	
	D	***H***	***S***	***fo%***	***fd%***	***fo%***	***fd%***	***fo%***	***fd%***	***IV ± SD***	***Groups***
Crypturellus parvirostri (Wagler, 1827) Small-billed Tinamou	O	Fr	R	4.17	0.06	4.17	0.06	4.17	0.21	12.50 ± 16.13	NC
Elanus leucurus (Vieillot, 1818) White-tailed Kite	C	Oa	R	16.67	0.25	-	-	-	-	33.3 ± 14.99	NC
Rupornis magnirostris (Gmelin, 1788) Roadside Hawk	C	Oa	R	16.67	0.25	4.17	0.09	-	-	80.00 ± 14.70*	NC
Milvago chimachima (Vieillot, 1816) Yellow-headed Caracara	C	Oa	R	4.17	0.06	-	-	-	-	25.00 ± 0.79	NC
Athene cunicularia (Molina, 1782) Burrowing Owl	C	Oa	R	-	-	-	-	4.17	0.43	50.00 ± 16.95	HD
Aramides saracura (Spix, 1825) Slaty-breasted Wood-Rail	O	Fr	R	-	-	-	-	4.17	0.21	25.00 ± 0.79	HD

Columbina talpacoti (Temminck, 1811) Ruddy Ground-Dove	G	Oa	R	100	12.22	87.50	7.38	79.17	14.56	59.5 ± 5.31**	NC
Patagioenas picazuro (Temminck, 1813) Picazuro Pigeon	G	Ed	R	4.17	0.13	-	-	-	-	16.7 ± 14.91	NC
Zenaida auriculata (Des Murs, 1847) Eared Dove	G	Oa	R	29.17	0.69	8.33	0.18	8.33	0.43	73.3 ± 11.98*	NC
Leptotila verreauxi Bonaparte, 1855 White-tipped Dove	G	Fr	R	45.83	0.88	20.83	0.46	83.33	13.28	55.7 ± 11.19	HD
Coccyzus melacoryphus Vieillot, 1817 Dark-billed Cuckoo	I	Ed	M	4.17	0.06	-	-	4.17	0.43	16.7 ± 14.86	HD
Crotophaga ani Linnaeus, 1758 Smooth-billed Ani	I	Oa	R	50.00	3.65	33.33	2.64	25.00	2.14	61.7 ± 8.22*	NC
Guira guira Leach, 1820 Guira Cuckoo	I	Oa	R	4.17	0.06	4.17	0.55	4.17	1.28	32.5 ± 14.07	HD
Tapera naevia (Linnaeus, 1766) Striped Cuckoo	I	Ed	R	-	-	16.67	0.36	-	-	75.00 ± 14.25*	HD
Hydropsalis albicollis (Gmelin, 1789) Pauraque	I	Ed	R	-	-	-	-	8.33	0.64	25.00 ± 0.79	HD
Phaethornis pretrei (Lesson & Delattre, 1839) Planalto Hermit	N	Ed	R	-	-	4.17	0.09	-	-	25.00 ± 0.79	PR
Chlorostilbon lucidus (Shaw, 1812) Glittering-bellied Emerald	N	Oa	R	45.83	1.64	20.83	0.46	20.83	1.93	48.3 ± 7.56	HD
Picumnus temminckii Lafresnaye, 1845 Ochre-collared Piculet	I	Ed	R	-	-	8.33	0.18	-	-	25.00 ± 0.79	PR
Colaptes melanochloros (Gmelin, 1788) Green-barred Woodpecker	I	Ed	R	4.17	0.06	-	-	4.17	1.28	21.4 ± 12.31	HD
Thamnophilus ruficapillus Vieillot, 1816 Rufous-capped Antshrike	I	Oa	R	37.50	0.63	37.50	1.00	8.33	0.64	45.5 ± 8.66	PR
Furnarius rufus (Gmelin, 1788) Rufous Hornero	I	Oa	R	16.67	0.44	12.50	0.36	4.17	0.43	47.7 ± 14.10	NC
Synallaxis spixi Sclater, 1856	I	Ed	R	37.50	0.88	70.83	2.37	4.17	0.21	63.4 ± 10.94	PR

Spix's Spinetail											
Myiornis auricularis (Vieillot, 1818) Eared Pygmy-Tyrant	I	Ed	R	8.33	0.13	25.00	0.64	-	-	58.8 ± 15.60	PR
Camptostoma obsoletum (Temminck, 1824) Southern Beardless-Tyrannulet	I	Oa	R	12.50	0.25	8.33	0.18	-	-	33.3 ± 14.96	NC
Elaenia flavogaster (Thunberg, 1822) Yellow-bellied Elaenia	O	Ed	R	16.67	0.38	-	-	4.17	0.43	75.00 ± 14.22*	NC
Serpophaga subcristata (Vieillot, 1817) White-crested Tyrannulet	I	Oa	R	25.00	0.63	37.50	1.09	8.33	0.64	46.2 ± 11.78	PR
Pitangus sulphuratus (Linnaeus, 1766) Great Kiskadee	O	Oa	R	58.33	1.83	25.00	0.64	33.33	2.36	67.4 ± 10.31*	NC
Megarynchus pitangua (Linnaeus, 1766) Boat-billed Flycatcher	O	Ed	M	8.33	0.13	-	-	-	-	25.00 ± 0.79	NC
Tyrannus melancholicus Vieillot, 1819 Tropical Kingbird	I	Oa	M	58.33	3.27	4.17	0.18	4.17	0.86	65.9 ± 11.25*	NC
Tyrannus savana Vieillot, 1808 Fork-tailed Flycatcher	I	Oa	M	29.17	1.83	4.17	0.09	29.17	3.85	85.2 ± 12.57**	NC
Myiophobus fasciatus (Statius Muller, 1776) Bran-colored Flycatcher	I	Oa	R	12.50	0.44	12.50	0.55	-	-	53.8 ± 14.11	NC
Empidonomus varius (Vieillot, 1818) Variegated Flycatcher	I	Oa	M	16.67	0.25	-	-	-	-	50.00 ± 14.02	NC
Satrapa icterophrys (Vieillot, 1818) Yellow-browed Tyrant	I	Oa	R	-	-	4.17	0.09	-	-	25.00 ± 0.79	PR
Progne tapera (Vieillot, 1817) Brown-chested Martin	I	Oa	M	8.33	0.19	4.17	0.18	-	-	10.7 ± 14.90	NC
Troglodytes musculus Naumann, 1823 Southern House Wren	I	Oa	R	83.33	2.33	79.17	2.55	16.67	2.78	45.1 ± 4.75	NC
Turdus rufiventris Vieillot, 1818 Rufous-bellied Thrush	O	Fr	R	8.33	0.13	-	-	8.33	0.43	37.5 ± 16.72	HD
Turdus leucomelas Vieillot, 1818 Pale-breasted Thrush	O	Fr	R	16.67	0.31	16.67	0.36	20.83	1.50	32.8 ± 10.84	HD

Turdus amaurochalinus Cabanis, 1850 Creamy-bellied Thrush	O	Fr	R	54.17	2.02	54.17	1.55	62.50	5.78	47.1 ± 4.43	NC
Mimus saturninus (Lichtenstein, 1823) Chalk-browed Mockingbird	O	Oa	R	4.17	0.25	-	-	4.17	0.21	20.00 ± 13.14	NC
Saltator similis d'Orbigny & Lafresnaye, 1837 Green-winged Saltator	O	Fr	R	41.67	1.26	54.17	1.73	16.67	1.07	47.6 ± 5.94	NC
Tachyphonus coronatus (Vieillot, 1822) Ruby-crowned Tanager	O	Fr	R	25.00	0.50	33.33	1.19	4.17	0.43	42.2 ± 12.15	PR
Lanio cucullatus (Statius Muller, 1776) Red-crested Finch	G	Ed	R	100.00	15.81	100.00	20.69	75.00	19.49	45.5 ± 4.83	NC
Lanio melanops (Vieillot, 1818) Black-goggled Tanager	O	Fr	R	-	-	4.17	0.09	-	-	25.00 ± 0.79	PR
Tangara sayaca (Linnaeus, 1766) Sayaca Tanager	O	Fr	R	8.33	0.25	4.17	0.09	-	-	40.00 ± 15.80	NC
Tersina viridis (Illiger, 1811) Swallow Tanager	F	Ed	M	4.17	0.06	-	-	-	-	20.80 ± 8.66	NC
Conirostrum speciosum (Temminck, 1824) Chestnut-vented Conebill	I	Fr	R	4.17	0.13	8.33	0.46	8.33	0.86	13.9 ± 15.87	PR
Ammodramus humeralis (Bosc, 1792) Grassland Sparrow	G	Oa	R	20.83	0.50	-	-	-	-	50.00 ± 13.90	NC
Sicalis flaveola (Linnaeus, 1766) Saffron Finch	G	Oa	R	41.67	2.71	4.17	0.09	12.50	1.50	84.3 ± 16.72	NC
Sicalis luteola (Sparrman, 1789) Grassland Yellow-Finch	G	Oa	R	8.33	0.25	8.33	0.64	12.50	1.07	13.3 ± 15.38	NC
Embernagra platensis (Gmelin, 1789) Great Pampa-Finch	G	Oa	R	50.00	1.76	16.67	0.55	16.67	1.07	47.7 ± 13.15	NC
Volatinia jacarina (Linnaeus, 1766) Blue-black Grassquit	G	Oa	R	95.83	16.18	91.67	24.25	41.67	8.78	47.4 ± 7.89	PR
Sporophila nigricollis (Vieillot, 1823) Yellow-bellied Seedeater	G	Oa	R	-	-	8.33	0.18	-	-	25.00 ± 0.79	PR
Sporophila caerulescens (Vieillot, 1823) Double-collared Seedeater	G	Oa	R	95.83	15.30	87.50	16.68	37.50	4.50	54.4 ± 9.94	NC

Cyanoloxia brissonii (Lichtenstein, 1823) Ultramarine Grosbeak	G	Oa	R	8.33	0.13	16.67	0.46	4.17	0.21	12.5 ± 16.13	PR
Geothlypis aequinoctialis (Gmelin, 1789) Masked Yellowthroat	I	Ed	R	87.50	3.27	79.17	5.01	25.00	2.57	42.00 ± 4.29	PR
Agelaioides badius (Vieillot, 1819) Bay-winged Cowbird	G	Oa	R	4.17	0.69	-	-	-	-	80.0 ± 13.98*	NC
Molothrus bonariensis (Gmelin, 1789) Shiny Cowbird	G	Oa	R	25.00	0.50	4.17	0.18	-	-	25.00 ± 0.79	NC
Sporagra magellanica (Vieillot, 1805) Hooded Siskin	G	Oa	R	45.83	3.97	37.50	3.46	16.67	1.50	57.3 ± 7.18	NC

APPENDIX 3

General data corresponding to status of occurrence, classes of occurrence, classes of dominance, preferential habitat and trophic guilds in the treatments applied nucleation (NC), passive restoration (PR) and high diversity plantation (HD). The abbreviations (*n* and *fr*) correspond, respectively, to total number of contacts and relative frequency. (*) signifies level of statistical acceptance at 5% of probability ($P < 0.05$) and (**) the level of 1% of probability ($P < 0.01$), as well as non-significant values (*ns* = $P \geq 0.05$) for the χ^2 test. SD = standard deviation.

Categories	NC		PR		HD		Test
	N	f_r	***n***	f_r	***n***	f_r	χ^2
Status of occurrence χ^2	23.59**	-	28.19**	-	23.36**	-	-
Resident	42	0.86	38	0.93	33	0.89	0.58ns
Migratory	7	0.14	3	0.07	3	0.08	1.40ns
Classes of occurrence χ^2	32.16**		33.27**		50.98**	-	-
Very abundant (80 ⊦100%)	6	0.12	4	0.10	1	0.03	2.20ns
Abundant (60 ⊦ 80%)	0	0	3	0.07	3	0.08	1.37ns
Frequent (40 ⊦ 60%)	10	0.2	2	0.05	1	0.03	11.18**
Occasional (20 ⊦ 40%)	8	0.16	9	0.22	7	0.19	0.09ns
Rare (1 ⊦ 20%)	25	0.51	23	0.56	25	0.68	0.25ns
Very rare (< 1%)	-	-	-	-	-	-	-
Classes of dominance χ^2	71. 30**	-	54.48**	-	19.62**	-	-
Eudominant (> 10%)	4	0.08	3	0.07	3	0.08	0.02ns
Dominant (10 ⊦ 5%)	0	0	2	0.05	2	0.05	0.56ns
Subdominant (2 ⊦ 5%)	7	0.14	4	0.10	6	0.16	0.36ns
Recessive (1 ⊦ 2%)	5	0.1	5	0.12	9	0.24	0.96ns
Rare (< 1%)	33	0.67	27	0.66	17	0.46	4.44ns
Preferential habitat χ^2	15.55**	-	14.98**		7.79*	-	-
Open areas	30	0.61	26	0.63	21	0.57	1.25ns
Forest	10	0.2	7	0.17	8	0.22	0.62ns

Edges	9	0.18	8	0.20	8	0.22	0.01ns
Trophic guilds χ²	29.79**		34.14**		25.83**		-
Omnivores	11	0.22	7	0.17	10	0.27	0.50ns
Nectarivores	1	0.02	2	0.05	1	0.03	0.06ns
Insectivores	18	0.37	18	0.44	14	0.38	0.65ns
Granivores	15	0.31	13	0.32	11	0.30	0.36ns
Frugivores	1	0.02	0	0.00	0	0.00	-
Carnivores	3	0.06	1	0.02	1	0.03	0.45ns
Exclusive species	8		6		3		1.43 ns
Total number of contacts	1582		1097		467		594**
Observed richness (Mao Tau) ± SD	49 ± 2.45		41 ± 2.79		37± 3.14		-
Richness (Jacknife 1) ± SD	50.38±3.50		42.3±3.62		38.2±4.06		-
Richness (Chao 2) ± SD	48.14±5.45		40.01±4.58		36.17± 6.45		-