Comparative analysis of birdlife in different ecological restoration methods with emphasis on the role of artificial perches

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Abstract: Artificial perches provide complexity to the landscape, a factor that can increase animal biodiversity. We tested the hypothesis that artificial perches used in ecological restoration promote increased birdlife diversity in a restored landscape in southern Brazil. The study was conducted in the southwest of Paraná State, on land used for years for agriculture and pasture. Estimates of species and diversity of avifauna in 12 experimental plots were obtained one year after the beginning of the restoration. Data from plots restored through nucleation, which consisted of inserting artificial perches, were used to create a data set analyzed with and without the records of birds obtained exclusively on artificial perches. These data were compared with those from experimental plots re-vegetated by either passive or active (i.e. high diversity planting) restoration. In addition, the ability of different restoration techniques to attract avifauna occurring in a nearby forest was investigated. Restored plots using nucleation had higher richness (42± 3.00SD species), abundance and diversity compared to passive restoration and high diversity planting. However, when the results obtained exclusively from artificial perches were disregarded, the pattern of the diversity components in the nucleation did not differ from that of the passive restoration. Thus, the artificial perches provided an additional niche and, in this study, represented 34% of the increase in the accumulated richness observed in nucleation. Thus, perches are an important natural engineering structure that can increase local bird richness.

Keywords: Atlantic rain forest, ecological succession, neotropical birds, restoration ecology.

A análise comparativa da avifauna em diferentes métodos de restauração ecológica com ênfase no papel de poleiros artificiais

Resumo: Os poleiros artificiais proporcionam complexidade à paisagem, um fator que pode aumentar a biodiversidade. Testamos a hipótese de que os poleiros artificiais utilizados na restauração ecológica são fatores que promovem riqueza específica de aves em uma paisagem restaurada no sul do Brasil. O estudo foi realizado no sudoeste do estado do Paraná, em uma área que serviu durante anos para

a agricultura e pastagem. Estimativas das espécies e da diversidade da avifauna foram obtidas em 12 parcelas experimentais um ano após o início da restauração. Dados de parcelas restauradas por meio da nucleação (este método consiste também em inserir poleiros artificiais) foram utilizados para criar um conjunto de dados analisados com e sem registros de aves obtidas exclusivamente em poleiros artificiais. Esses dados foram comparados com os de parcelas experimentais revegetadas por restauração passiva ou ativa (plantação de alta diversidade). Além disso, investigamos a capacidade de diferentes técnicas de restauração para atrair avifauna ocorrendo em uma floresta próxima. As parcelas restauradas com nucleação apresentaram maior riqueza (42 ± 3,00DP espécies), abundância e diversidade em relação à restauração passiva e plantio de alta diversidade. No entanto, quando os resultados obtidos exclusivamente a partir de poleiros artificiais foram desconsiderados, o padrão dos componentes de diversidade na nucleação não diferiu do modelo da restauração passiva. Os poleiros artificiais forneceram um nicho adicional e, neste estudo, representaram 34% do aumento da riqueza acumulada observada no tratamento de nucleação. Desse modo, poleiros são importantes estruturas de engenharia natural que causa aumento local da riqueza de aves.

Palavras-chave: Mata Atlântica, sucessão ecológica, aves neotropicais, ecologia da restauração.

Introduction

The abandonment of pastures and croplands permits environmental colonization by diverse bird species, whose roles were previously limited to agroecosystem pioneer species (Fuller et al., 2001). This process occurs because constant changes are promoted by livestock and agricultural management (Haslem & Bennett, 2008). Thus, changes in the structure of agricultural landscapes promote direct alterations in the composition of bird assemblages (Báldi & Bátari, 2011; Sanderson et al., 2013). This process is dynamic, influenced by the distance between the forest fragments (Akçakaya et al., 2007) and by the size and quality of the new habitat patch (Fink et al., 2009).

Some birds are associated with certain phases of forest regeneration. They are mobile in the landscape, rapidly colonizing environments in the initial process of regeneration (Schieck & Song, 2006). These species later disappear or are replaced during ecological succession (Odum, 1950).

Other birds are adapted to more stable environments and depend on the integrity of primary forests (Anjos, 2006). Thus, there is a very dynamic alternation of ecological release, followed by a competitive increase within each phase of ecological succession, causing cycles of new colonization and local extinctions (Wright, 1980; Anjos, 2004).

Recently restored environments can serve as partial or temporary habitats, decreasing the competition for resources within adjacent forests (Esler, 2000; Akçakaya et al., 2007). Thus, ecological restoration creates new forest niches, which gradually appear in the landscape. Using this mechanism, birds occurring in stable areas gradually colonize restored environments, increasing their similarity to nearby forests in terms of faunistic composition (Reid et al., 2012).

Diverse strategies have been used to increase the speed of ecological restoration, such as applied nucleation (Reis et al., 2010; Corbin & Holl, 2012). This technique utilizes a set of procedures involving planting trees in nuclei, the use of shelters for fauna, artificial perches for avifauna, planting of seed banks and seed rain, and the use of living mulch in nuclei. These procedures are based on the facilitation mechanism that favors the arrival and establishment of new species of flora and fauna in the habitat (Yarranton & Morrison, 1974; Reis et al., 2003).

Applied nucleation is an alternative to the conventional planting of pure and mixed tree species (Jordan et al., 2003; Corbin & Holl, 2012; Van-Andel & Aronson, 2012; Zahawi et al., 2013). In the same way, plantations of native species are an appropriate choice, because they allow the insertion of elevated floristic richness, which attracts animals (Wunderle-Jr., 1997; Rodrigues et al., 2011). However, in certain situations, they can present low structural complexity, because they are characteristic of more senescent forests (Brady & Noske, 2010).

One of the more relevant techniques for attracting birds to recently restored areas is the use of artificial or natural perches (Verdu & Garcia-Fayos, 1996). In nature, birds use dry trees as perches to observe prey, perform courtship and mating displays, eat insects inhabiting the bark and wood, or to rest between forest fragments (Holl, 1998; Bocchese et al., 2008; Ortega-Alvarez & Cisneros, 2012). Artificial bird perches can also act as hunting and resting areas for some hawk and owl species that prey on animals that can jeopardize the restoration and thus decrease their incidence (Hall et al., 1981; Pias et al., 2012). In addition, perches attract birds that feed on fruit, contributing to zoochorous dispersal of seeds of woody plants (Shiels & Walker, 2003; Graham & Page, 2012).

Many bird species possess a clear preference for perches (Holl, 1998; Guedes et al., 2006; Vi-

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cente et al., 2010). These perches, in turn, can lead to an increase in the architecture of the environment (structural complexity), which increases the number of available niches (Willson, 1974; Hulbert, 2004; Horgan et al., 2016). Thus, theoretically, artificial perches can increase the structural complexity of the landscape (McDonnel & Stiles, 1983; Pillatt et al., 2010; Horgan et al., 2016), favoring an increase in the local richness of the bird assemblage.

We hypothesized that artificial perches used in nucleation are crucial for promoting richness in the assemblage of birds that initially recolonize altered habitats. Moreover, we compared the richness, abundance, and diversity of birds that occur in restored habitats, using different restoration techniques. During the first 2 years of restoration, we tested (a) the effect of artificial perches used in habitats restored under nucleation in relation to the total variation of the richness, abundance, and diversity of the assemblage; (b) the preference of different guilds in relation to the treatments and experimental groups; and (c) the capacity of the restoration techniques used in the service of a partial habitat for birds that occurred in a nearby forest fragment, which theoretically functions as a source area of species for restored plots.

Materials and Methods

Study area

The experiment was conducted on the area adjacent to a legal reserve of the campus of Federal Technological University of Paraná (*pt.*, UTFPR) in the municipality of Dois Vizinhos, state of Paraná, Brazil, Fig. 1. The region is an ecotone between a "Mixed Ombrophilous Forest" or Araucaria Moist Forest, and the "Seasonal Semideciduous Forest" or Alto Paraná Forest. The area is categorized as transitional in two climate zones: *Cfb* and *Cfc* from the Köppen climate classification system. The altitude is approximately 500 m and the amount of annual rainfall is approximately 1,800–2,000 mm (Gerber et al., 2017). Latosolos (Oxisols; Bw) predominate the site, which are generally deep and historically used in successive plantings.
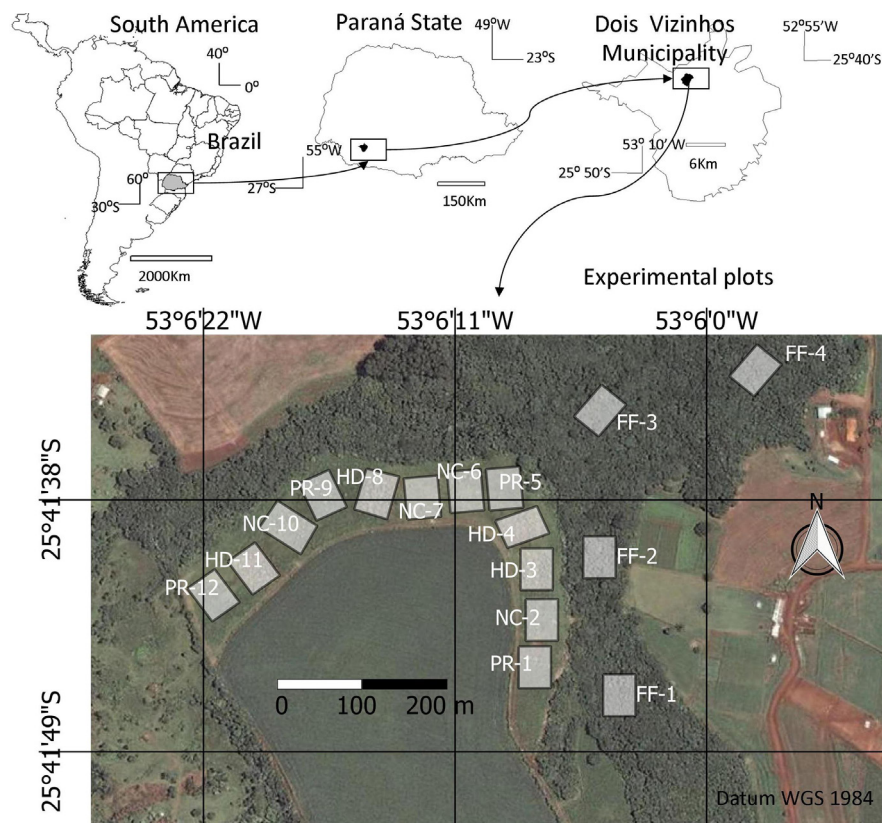
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Fig. 1. Map indicating the location of the study area and experimental plots. Characteristics of the landscape, containing nucleation (NC), passive restoration (PR), and high-diversity planting (HD) and plots in the forest fragment (FF) that borders the experimental area can be observed. Adapted from Google Earth (2015).

Between 1993 and 2005, wheat and oats were cultivated in winter, while corn, soybeans, and kidney beans were cultivated in summer. The site was used as pasture between 2006 and 2008. To this end, forage species such as African Bermuda-grass (*Cynodon nlemfuensis*), Guinea grass (*Megathyrsus maximus*), and Signal grass (*Brachiaria decumbens*) were inserted. In 2010, there were annual cultures until the last harvest of the year (October).

Experimental design

The experiment (Fig. 1) was designed by F.C.B and arranged in 12 randomly distributed plots (40 × 54 m). Each treatment included four replications, totaling 8.640 m² or 0.86 hectares. The treatments were nucleation (NC), passive restoration (PR), and high-diversity planting (HD), an active restoration methodology. The plots were arranged 13 ± 5 m (±SD - standard deviation) apart and 20.6 ± 5.7 m from the nearby forest fragment, whose boundaries were clearly indicated by wooden rods. In October 2010, the whole area was cleared using a lawn tractor, initiating soil preparation. In December, seedlings began to be planted.

Ecological restoration techniques

The general planting procedures (to NC, PA, and HP) involved harrowing of the soil to a depth of about 5 cm. In December 2010, holes were manually opened to a depth of 20 cm and formicide baits were arranged in traps surrounding the experimental area. In NC, seven nucleation techniques were used, adapted from previous studies (Reis et al., 2010; Bechara et al., 2016), in six 3 × 40 m strips per plot, occupying 33.33% of the total area. Two structural and five procedural techniques were used in each plot (Fig. 2a). The structural techniques consisted of: (1) use of a stereometric volume (1 × 1 × 1 m woodpile)

for the fauna; (2) two artificial perches (10 m high and mean diameter between 15 and 20 cm), made from dry trunks of eucalyptus (*Eucalyptus grandis*). The winged-stem passion fruit (*Passiflora alata*) was cultivated at the base of each perch, as described by Reis et al. (2003).

The five procedural techniques included: (3) six seed banks (area: 1 m²; depth: 10 cm), which were collected *in natura*, deposited in trays, and cultivated in nurseries. The seedlings that germinated were later transferred to the field. Six 1 m² blocks of seed rain per plot were also inserted (4). The seed rain was obtained by means of 30 collectors (area: 1 m²). The material obtained from the collectors was homogenized and cultivated in nurseries.

The seedlings, as well as ungerminated seeds, were later transferred to the field. The seed bank and seed rain were obtained in a secondary forest remainder (25°36'22"S; 53°48'.20"W) with the objective of potentiating natural regeneration with local species. In order to attract pollinators that can serve as food for the fauna in restored areas (Golawski & Golawska, 2013), as well as to increase the biomass of the soil (Beltrame & Rodrigues, 2008), the pigeon pea *Cajanus cajan* (5) was sown in 12 nuclei with 3 × 4 m nuclei, with six rows and a density of approximately 20 seeds per linear meter.

In total, 24 densely vegetated nuclei were planted. They were composed of five seedlings (6), which were planted 1 m apart and arranged in a "+" form. There were four rapid-growth pioneer seedlings at the edges, and one shaded non-pioneer species in the center, as described by Anderson (1953). In total, 12 pioneer species and 24 non-pioneer species were used. They are listed in Annex 1 (556 seedlings ha⁻¹). Finally, (7) six groups of bromeliads "caraguatá" (*Bromelia antiacantha*) were inserted in nuclei with five seedlings, 0.5 m apart, and arranged in a "+" form (Anderson, 1953).
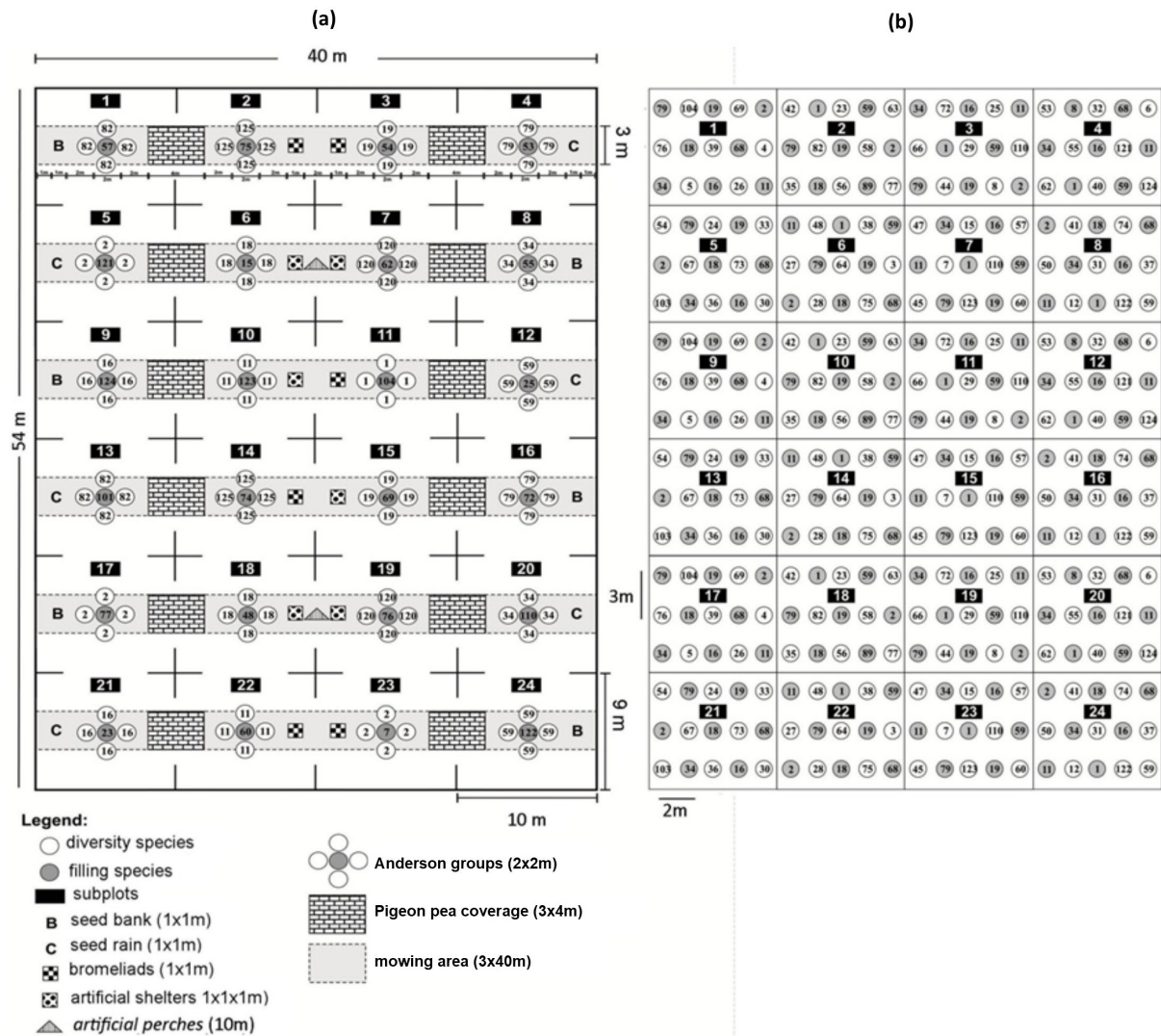
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Fig. 2. Experimental design used in the nucleation (a) and the high-diversity planting (b). The numbers correspond to the species described in supplementary document 1. Adapted from a previous study (Vogel et al., 2015).

The passive restoration treatment (PR) had a dual function. In addition to the treatment, it was also used as a local control, because a natural regeneration area with the same age as the other treatments is necessary for comparison. Since the perimeter had been delimited, the area was only protected against disturbances such as fire and grazing (Shono et al., 2007; Rey-Banayas et al., 2008).

High-diversity tree planting (HD) was based on the technique of fillings and diversity lines (Gonçalves et al., 2005; Gandolfi et al., 2007; Rodrigues et al., 2009, 2011). In total, 70 regional tree species were used (supplementary document 1), of which 10 were pioneer (filling) and 60 non-pioneer (diversity; secondary and climax) species. The seedlings were inserted in the field at heights varying between 20 and 35 cm, systematically alternating filling and diversity species (Fig. 2b).

Regarding NC and HD, quarterly mowing was carried out, starting from the implementation date, and seedlings were weeded using glyphosate®. In HD, the lianas and herbaceous vegetation was totally removed, leaving the soil exposed, and the vegetation was introduced by planting. In NC, management by mowing occurred with the same periodicity as in HD, only in the six 3 × 40 m strips per plot (33.33%) of the total area (only where the techniques were inserted). To implant the five procedural techniques in NC and seedlings in plots in the forest fragment (FF), chemical fertilizer (NPK: 05-20-10, dose: 30 kg/ha of N; 120 kg/ha of P_2O5; 60 kg/ha of K_2O) was used. The woody species used are detailed in supplementary document 1.

Part of the vegetation in the fragment has been removed, with disturbances ceasing approximately 30 years ago. At that time, about 1 ha

of loblolly pine (*Pinus taeda*), 0.5 ha of Camden white gum (*Eucalyptus benthamii*), and 0.5 ha of Japanese raisin tree (*Hovenia dulcis*) had been inserted. The fragment is in the initial/middle secondary stage of regeneration, isolated by an agroecosystematic matrix composed of pastures and plantations. The species with the 10 highest importance values (IV) formed 78% of the total value; for example, *Matayba elaeagnoides*, *Luehea divaricata*, *Sebastiania commersoniana*, *H. dulcis*, *Parapiptadenia rigida*, *Nectandra lanceolata*, *Ocotea puberula*, *Casearia decandra,* and *Campomanesia xanthocarpa* (Gorenstein et al., 2011).

Data collection

Twenty-four samplings (six per season) were carried out from January to December 2012, with a sampling effort of eight hours per plot or 96 hours during the whole experiment. The bird census was conducted 1 year after the beginning of the restoration, with richness and abundance determined by directly counting the individuals by means of a single sampling point in the center of each experimental plot (Bibby et al., 2000). However, only records of birds perched were considered. Sampling was performed every 15 days; nevertheless, some observations were postponed due to adverse weather conditions (i.e. rain and wind). As far as possible, sampling was standardized and carried out on sunny days or days with light rain (< 5 mm/day).

Each sampling lasted 20 min (10 in the morning and 10 in the afternoon). The census started when the sun was at an angle of approximately 5° on the horizon (~06h 30s to ~08h 40s, -3GMT). In the afternoon, the sun was at 45° (~16h 30s to ~18h 30s). This design was chosen because 20 consecutive minutes would greatly increase the chance of resampling the same individuals. Dividing the 20 min into two 10 min periods can also lead to an overestimation of abundance; however, it increases the chance of detecting discrete species (Vielliard et al., 2010).

The starting plot was randomly assigned, and the trajectory was always from the first to the last plot (1→12). In the adjacent forest fragment, four equidistant (approximately 150m) listening points (Anjos, 2007) were used, using colored tags as markers, distributed on the observation perimeter to match the sampling area of the experimental plots, with the same sampling procedures carried out in the experimental plots and sampling direction (1→4). The nomenclature used to identify birds was consistent with the Brazilian Committee of Ornithological Records (Piancintini et al., 2015).

Data analysis

Regarding the plots restored by nucleation, the records obtained from the artificial perches were separated from the rest of the data (soil + vegetation), creating the artificial group NC-AP. Conversely, a second group containing only the records obtained from the artificial perches (AP) was created. This design was selected to determine the contribution of the birds to the component parameters of diversity, allowing the free possibility of the birds occupying both the perches and the vegetation/soil, which would not be possible in treatments that had a design with and without perches. Four treatments (FF, NC, PR, and HD) and two artificial groups (NC-AP and AP) were dealt with. Of note, FF was not specifically a treatment, but a species source area. However, it was interpreted as a treatment for analytical purposes.

Species richness estimates (Jackknife 1 and Chao 2) were obtained for each treatment and artificial group, as well as the collector's curve, using observed richness, Sobs – Mao Tau with 10,000 permutations (Colwell et al., 2004). To this end, the software Stimates® was used (Colwell, 2011). Further, with observed abundance (N) and richness (S) as a base, the Shannon-Weaver index (H') and the Pielou uniformity index (J') were estimated for each sample (Krebs, 1999).

To obtain evidence to support the hypothesis, the mean values of the richness, abundance, and diversity parameters were obtained in each sampling were submitted to an analysis of variance (two-way ANOVA) with six groups [(FF, NC, PR, and HD) and two artificial groups (NC-AP and AP)]. The plots were pseudoreplicates and the 24 samplings were repetitions. A *post hoc* Tukey test was then carried out. To evaluate the presuppositions of the analysis, the Shapiro-Wilk test for normality and the Bartlett test for homogeneity of the variances were used (Quinn & Keough, 2002). Data were analyzed using the program Statistica® 7.0 (Statsoft INC., 2004).

To complement the interpretation of the role of artificial perches as an additional niche in NC, an ordination of the experimental plots and the groups was carried out. These data were ordered by means of principal components analysis (PCA), using the broken-stick criterion to reduce the axes to be interpreted (Johnson & Wichern, 2007). Berger-Parker – D dominance values were used as quantitative variables (Melo, 2008), and were obtained from the total contacts of each species per plot. The scores of the axes between treatments were later tested using the Kruskal-Wallis-KW[2] non-parametric variance analysis (Corder and Foreman, 2009). These tests were performed using the computational tools Pc-Ordtm ver. 6 (McCune & Mefford, 2011) and PAST® ver. 2.17 (Hammer et al., 2001). With the use of this procedure, it was possible to obtain Pearson correlation values between species and axes, which were converted into correlation classes: strong correlation (±) 0.85 ⊢ (±) 1, moderate correlation (±) 0.75 ⊢ (±) 0.85, weak correlation (±) 0.60 ⊢ (±) 0.75, and no correlation (< ± 0.6).

The species were grouped using a proposal of mixed guilds alpha (α) and beta (β) similar to that described by Almeida et al. (2003). In this system, based on Telino-Júnior et al. (2005), α corresponds to the predominant diet: insectivorous (I), omnivorous (O), frugivorous (F), granivorous (G), nectarivorous (N), and carnivorous (C). In turn, β means preferred habitat, as follows: open areas (OA: agricultural areas, abandoned fields, and pasture), forests (FO: birds that occur in secondary forests, understory, and emergent canopy), and edges (ED: species common to the forest margin and insensitive to the edge effect and tolerant of the partial destruction of the forest habitat (Ries & Sisk, 2010; Scherer-Neto & Toledo, 2012). This guild proposal allows greater precision for group separation, making comparisons more robust. The proportions of individuals in each guild were compared between treatments and artificial groups using the chi-square (χ^2) test with the null hypothesis of equality - α = 0.05 as the minimum limit of statistical acceptance, using, when necessary, the Yates correction (Preacher, 2001).

The ordination was carried out by means of detrended correspondence analysis (DCA), using the total abundance of individuals in each guild as variables and the sampling repetitions for each treatment as categories. Thus, it was possible to obtain Pearson correlations between guilds and axes. This test was performed to verify the possibility of guilds with a greater relationship to a given treatment or group. This analysis was performed using Pc-Ord™ ver. 6 (McCune & Mefford, 2011). The scores of the axes between treatments and groups were tested using one-way analysis of variance (ANOVA) and the *post hoc* Tukey test (Quinn & Keough, 2002).

To evaluate which groups or treatments were most similar to the bird assemblage in the source area, the similarity percentages – SIMPER (Clarke, 1993) were analyzed between treatments and groups was used, based on the annual total of records for each plot. Percentages of the species that contributed most to the dissimilarity between treatments and groups, and also to the total dissimilarity were obtained. Based on the data matrix, the ANOSIM test was used, which compared the groupings formed by the cluster analysis (Bray-Curtis dissimilarity), with application of the Mann-Whitney *post hoc* test of pair-wise comparisons (Clarke, 1993). Both tests were carried out using the program Past® ver. 2.17 with 10,000 permutations (Hammer et al., 2001).

Results

In total, 4,139 contacts of 88 species distributed in 31 families were obtained. The most representative family was Thraupidae (n = 15; 17.05%), followed by Tyrannidae (n = 13; 14.77%). Twenty-four-percent of the total records were obtained in FF and 38.22% in NC. Regarding AP, 451 contacts were observed for 15 families. The highest accumulated richness was found with the FF treatment (60 ± 2.88 SD species), followed by NC (42 ± 3.00 SD). The collector's curve demonstrated a pattern very close to that found between NC-AP and PR (Fig. 4a). Estimates of richness (Jackknife 1 and Chao 2) were very close to the observations, showing that the sampling was satisfactory (Fig. 4b). The highest richness means per sampling were obtained in NC (6.83 ± 0.27 SD) and FF (6.68 ± 0.27 SD), with variation between artificial groups and treatments (Fig. 4c).

The initial hypothesis was supported, because the Tukey test demonstrated that NC-AP did not diverge from PR, inferring that perches are structural factors that influence the richness in the nucleation. Moreover, in relation to richness, there was no divergence between HD and AP. A differentiated pattern was observed for the abundance in NC, which presented a higher mean number of individuals per sample (16.47 ± 0.59 SD ind. $F_{[5.567]}$ = 36.38; P = 0.00). No variation in abundance was observed between FF, NC-AP, and PR; however, these treatments were distinct from HD and AP based on the results of the Tukey's test (Fig. 4d). The same pattern observed for richness was found for diversity (Fig. 4e). Descriptive analysis using Pielou uniformity (J') confirms that FF presented the highest mean (J' = 0.94 ± 0.27 SD J' units), followed by the smallest coefficient of variation (CV = 2.08%), contrary to that observed for AP (0.57 ± 0.27 SD; CV = 52.04%). More details are provided in Fig. 4f.
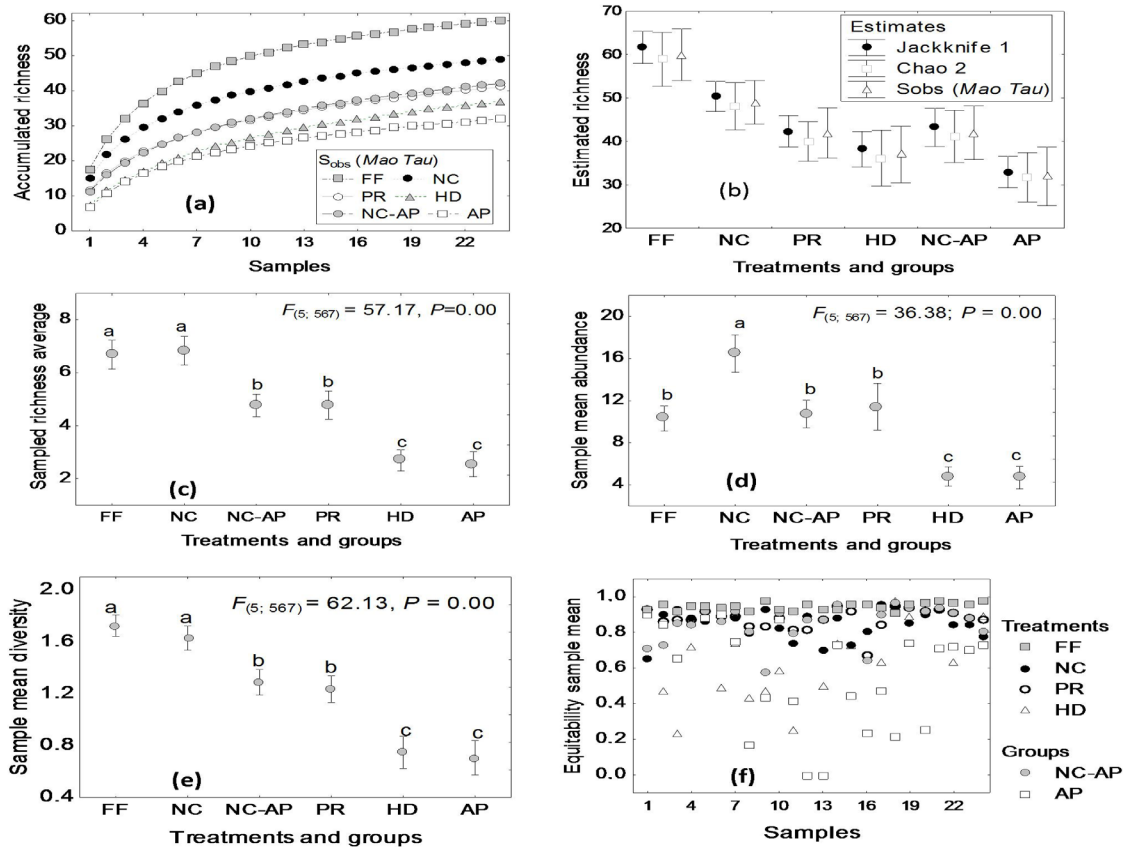
Fig. 4. Graphic representation of various parameters over seasons and samplings, as follows: (a) collector's curve for observed richness; (b) accumulated richness (Mao Tau) and estimated richness (Jackknife 1 and Chao 2), followed by the respective confidence intervals (95%). Figure (c) demonstrates richness means between treatments and groups for each sampling; abundance (d) and diversity (e). Confidence interval = 95%, means followed by the same letter do not differ based on the Tukey test (0.05%). Annual variation in Pielou uniformity (J') for treatments and groups (f) is also shown.

The PCA demonstrated that the general pattern of abundance and richness for NC differs from that of PR (Fig. 5a). However, when records from the artificial perches (NC-AP) are discarded, this segregation does not exist. Thus, perches are sufficient to distinguish between the bird assemblage occurring in NC and PR, because they segregate for both PC 1 and PC 2 in relation to the artificial group NC-AP and other treatments (Fig. 5a-b). The first two axes of the PCA retained 60.05% of the total variance (Tab. 1).

In general, the variables (species) were weakly or uncorrelated with the axes (Tab. 1). *Tyrannus melancholicus* (r = 0.89), *Molothrus*

bonariensis (r = 0.80), *Spinus magellanicus* (r = 0.71), *Furnarius rufus* (r = 0.70), *Zenaida auriculata* (r = 0.69), *Columbina talpacoti* (r = 0.67), *Tyrannus savana* (r = 0.64), and *Sicalis flaveola* (r = 0.60) were essential species in the segregation of AP regarding NC, and were positively correlated with PC 2. Specialized frugivores were absent from the perches, probably due to the defaunation recorded in the source area (FF), reflected in the experimental plots, because the only forest frugivorous species observed in FF, *Chiroxiphia caudata* and *Pteroglossus castanotis*, were not recorded in plots or on perches.
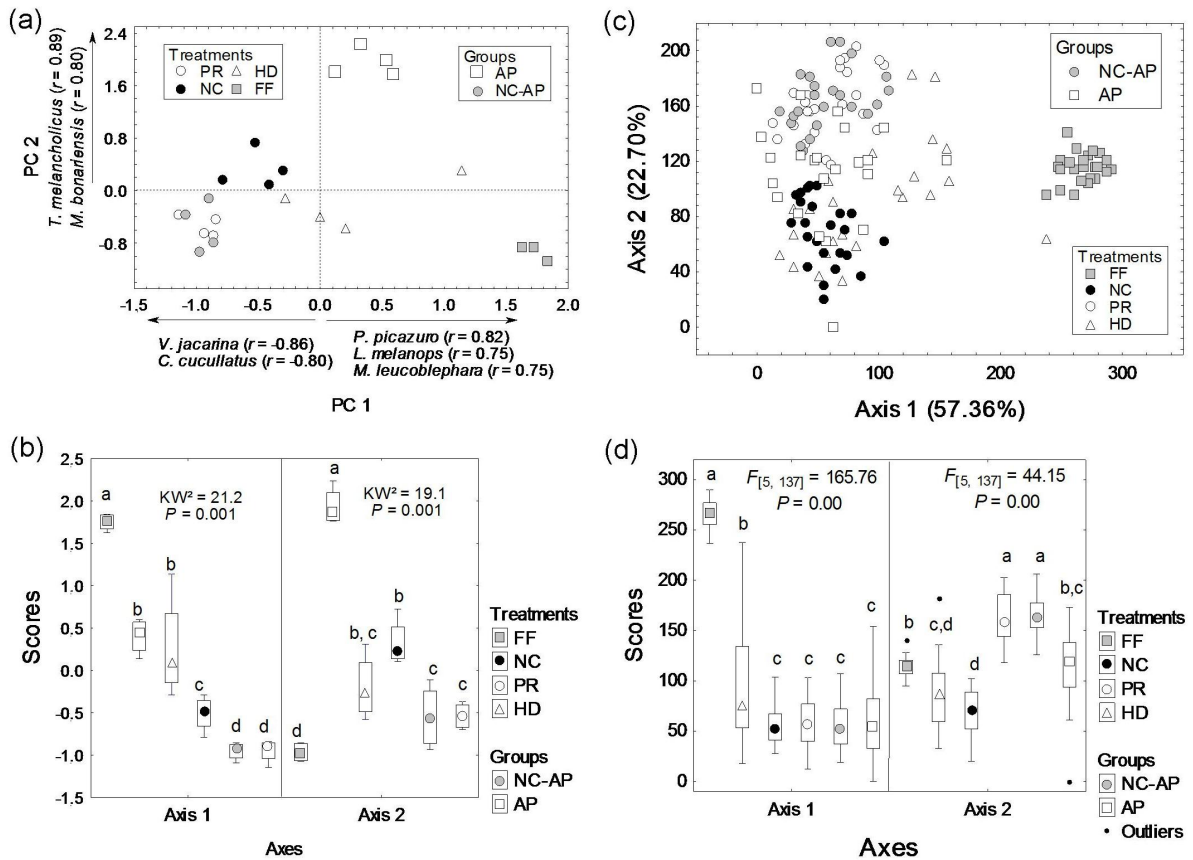
Fig. 5. Principal components analysis (a) between treatments (FF, NC, PR, and HD) and artificial groups (NC-AP and AP). It was tested of the axes using Kruskal-Wallis (KW²) non-parametric analysis of variance (b). Means followed by the same letter do not differ based on the Mann-Whitney post hoc test of pair-wise comparisons. Also shown are ordination of bird guilds by Detrended Correspondence Analysis (DCA) for experimental treatments and artificial groups (c) and (d) test of the axes using Analysis of Variance (ANOVA). Means followed by the same letter do not differ based on the post hoc Tukey's test.

Tab. 1. Variances, eigenvalues and, classes of Pearson correlations obtained by means of principal components analysis (PCA).

Axes	Axis 1		Axis 2	
Variance	41.79%		18.25%	
Eigenvalues	0.02		0.01	
Classes of correlation	(+)	(-)	(+)	(-)
Null	42	24	13	66
Weak	15	2	7	0
Moderate	3	1	1	0
Strong	0	1	1	0

Regarding the composition of mixed guilds, a high incidence of insectivores at the edges (IED and GED) and granivores in open areas (GOA) was found for each treatment (Tab. 2). It was only possible to verify variation in the proportions between treatments and artificial groups (χ^2 = 50, 85; df = 5; P = 0.00) for the trophic grouping of insectivores in forests, with 16 (27%) species in FF. Species from this guild did not occur in NC-AP. The test was not sensitive enough to detect variation between forest omnivores (χ^2 = 7.67; df = 5; P = 0.17). However, the guild presented twice the number of species observed in relation to the second group, which exhibited a higher abundance.

Tab. 1. Bird guilds occurring in the experimental treatments and artificial groups. (cy) indicates that the Yates correction was used in the chi-square (χ^2) test. OAC = open area carnivores; FEF = forest edge frugivores; FOF = forest frugivores; OAG = open area granivores; FEG = forest edge granivores; FOG = forest granivores; FEI = forest edge insectivores; OAI = open area insectivores; FOI = forest insectivores; FEN = forest edge nectarivores; OAN = open area nectarivores; FEO = forest edge omnivores; OAO = open area omnivores; FOO = forest omnivores.

Guilds	Treatments				Groups		Test	
	FF	NC	PR	HD	NC-AP	AP	χ^2	P
OAC	2	3	1	1	2	2	0.545**cy**	0.99
FEF	1	1	0	0	0	0	0.50**cy**	1.99
FOF	2	0	0	0	0	0	4.50**cy**	0.48
FOG	2	1	1	1	1	0	1.50**cy**	0.91
FEG	3	2	1	1	2	1	0.50**cy**	0.99
OAG	4	12	11	9	12	10	3.00	0.70
FEI	6	5	5	5	4	2	2.11	0.83
FOI	16	1	1	1	0	1	50.85**cy**	0.00
OAI	4	12	12	8	11	7	5.78	0.33
FEN	1	0	1	0	0	0	0.50**cy**	0.99
OAN	1	1	1	1	1	1	1.50	0.91
FEO	3	2	0	1	1	2	1.33**cy**	0.93
OAO	1	2	1	2	1	2	0.00**cy**	1.00
FOO	14	7	6	7	7	4	7.67	0.17
Total	14	12	11	11	10	10	0.54	0.97

Ordination of guild abundance (Fig. 5c) allows FF segregation on axis 1 to be verified in relation to the other treatments and groups. The analysis was mainly influenced by forest insectivores (r = 0.83), forest omnivores (r = 0.78), and forest granivores (r = 0.78). There was segrega-tion (only on axis 2) between NC and NC-AP (Fig. 5c-d), where forest edge granivores (r = 0.68) positively influenced NC-AP, while open-area insectivores negatively influenced NC on axis 2, which segregated from NC-AP and PR (r = -0.58). Details are provided in Tab. 3 and Fig. 5.

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Tab. 3. Correlation values between the abundance in guilds (variables) and axes of the detrended correspondence analysis (DCA). OAC = open area carnivores; FEF = forest edge frugivores; FOF = forest frugivores; OAG = open area granivores; FEG = forest edge granivores; FOG = forest granivores; FEI = forest edge insectivores; OAI = open area insectivores; FOI = forest insectivores; FEN = forest edge nectarivores; OAN = open area nectarivores; FEO = forest edge omnivores; OAO = open area omnivores; FOO = forest omnivores.

Guilds	Axis 1 (r)	Axis 2 (r)
OAC	-0.126	-0.394
FEF	0.232	0
FOF	0.247	-0.035
FOG	0.782	0.061
FEG	-0.097	0.686
OAG	-0.552	0.202
FEI	-0.214	-0.375
FOI	0.833	-0.114
OAI	-0.455	-0.581
FEN	0.45	-0.018
OAN	-0.135	0.159
FEO	0.43	-0.087
FOO	0.786	0.005
OAO	0.134	-0.072
Eigenvalues	**0.57**	**0.22**

Using the SIMPER test (Tab. 4), the assemblages between treatments and groups were not found to be similar to the source fragment. The highest dissimilarity was between FF and AP (93.7) and the lowest between FF and HD (84.1). *Turdus leucomelas* contributed most to the dissimilarity between FF and HD (8.51% of the variation). Between AP and NC-AP, the abundance of *Sporophila caerulescens* provided 15.63% of the dissimilarity. This species had the greatest influence on the dissimilarity between NC and PR (16.23%). The dissimilarity between NC-AP and PR was related to the abundance of *Volatinia jacarina* (19.82%).

Simultaneous comparison of the groups (SIMPER) revealed a total dissimilarity of 69.07%. This was mainly influenced by the abundance of *V. jacarina* (13.33%), which was not recorded in FF. According to the multivariate analysis of similarity (ANOSIM), FF and HD formed distinct groups, while NC, PR, and NC-AP formed a group.

Tab. 4. Bray-Curtis dissimilarity in relation to the similarity of percentages (SIMPER). Probability values for pairwise comparisons of the multivariate analysis of similarity (ANOSIM) are in italics. Values with (*) represent significant probabilities ($P < 0.05$), demonstrating differences between treatments or groups.

	FF	NC	PR	HD	NC-AP	AP
FF	-	91.33	93.20	84.10	92.50	93.70
NC	0.028*	-	38.98	66.47	35.73	63.09
PR	0.029*	0.060	-	62.04	32.96	69.07
HD	0.028*	0.030*	0.030*	-	60.72	64.91
NC-AP	0.027*	0.029*	1	0.027*	-	69.69
AP	0.031*	0.145	0.030*	0.030*	0.030*	-

Discussion

The species total (n = 88) represents approximately 48% of that observed in fragments of seasonal semideciduous forest in northern Paraná state (Bornschein & Reinert, 2000) and ∼73% of that reported by Bispo & Scherer-Neto (2010) in a fragment of a mixed ombrophilous forest in the eastern part of the state. Both studies were performed in forest fragments surrounded by an agricultural matrix. Thus, as this was an ecotone between a seasonal and ombrophilous forest, only a fraction of the species total with occurrence potential were recorded.

Richness estimators (Jackknife 1 and Chao 2) demonstrated sufficient sampling of the local avifauna. Total richness was similar to that observed by Pillatt et al. (2010) with 87 species in seasonal forest remainders and agricultural areas in southern Brazil, although species composition differences were noted. The structural characteristics of the avifauna occurring in this study demonstrated a pattern that is expected for altered areas, lacking species that are highly susceptibile to disturbances (Anjos, 2004, 2006) and bioindicator families, such as Dendrocolaptidae (Poletto et al., 2004).

Richness was lower with every treatment and group compared with the forest fragment. According to Fuller et al. (2001) and Herzon et al. (2014), recently restored environments do not fully support forest species, but can function as complementary habitats, alleviating the pressure of competition between some species and increasing regional diversity through the creation of a land-use mosaic. This pattern is consistent with the findings of Lindell et al. (2012), whereby recently restored environments were capable of furnishing environmental value to many bird species.

The analysis of variance for richness, abundance, and diversity (Fig. 4a-c) indicates that applied nucleation is similar to passive restoration when records obtained from the artificial perches are discarded. Therefore, the initial hypothesis was supported. The artificial perches provided an additional niche and, in this study, represented 34% of the increase in the accumulated richness observed in NC. According to some researchers, this role of the perches partially substitutes the bird-attracting function of isolated trees in agricultural landscapes, producing more environmental complexity (Bocchese et al., 2008; Sheldon & Nadkarni, 2013).

Evenness variation was the highest in FF. This infers that dominance is lower in FF and suggests a stability gradient (FF > NC > PR > HD), corroborating the findings of Reis et al. (2007), who stated that "nucleating actions are complemented in the sense of rapidly forming a more stabilized community."

It is interesting to note that during 2 years of restoration, AP provided an ecosystem value as important as that of HD, because the metric parameters that compose the diversity were similar, with no statistical differences based on the tests used. According to Ortega-Álvarez et al. (2013), removal of the understory vegetation limits the number of species in restored environments. This limitation occurs due to the reduced foraging strata (Lindenmayer et al., 2010). Thus, management in high-diversity planting, with the removal of emergent herbaceous vegetation, reduces the number of available niches and, therefore, limits the number of species (Vickery et al., 2002).

The Thraupidae family with the greatest species richness is directly related to the recent inclusion of the family Emberizidae (Piacentini et al., 2015). However, similarity in terms of accumulated richness between AP and HD is probably related to the abundance and richness of the family Tyrannidae. According to Gabriel & Pizo (2005); Silva et al. (2010), and Martins-Oliveira et al. (2012), flycatchers use both dry perches and plant canopies to forage for insects. Thus, AP and HD furnish this group a similar niche, because young trees provide natural perches during the two years of growth. Flycatchers are frequently observed carrying out frugivory in both forest habitats and in altered environments, making them insectivores or generalist omnivores with the ability to consume fruits and disperse intact seeds (Pizo, 2004, 2007; Athiê & Dias, 2012).

The attention given to species that perform frugivory and dispersal in ecological restoration studies limits our understanding of perch use patterns of granivorous birds, as well as their importance. In this study, open-area granivores and forest edge granivores represented 34.37% of the total species in AP. The highest abundance per sample was recorded in NC; however, the exclusion of records obtained from the artificial perches showed a similar pattern between NC-AP and PR. Thus, the abundance observed on the perches is believed to be influenced by gregarious species (e.g., *S. magellanicus* and *M. bonariensis*), as the PCA suggests. This overestimates the abundance of the sample (Ortega-Álvarez et al., 2013).

Perches are used in different ways by granivorous birds (Shiels & Walker, 2003; Bocchese et al., 2008). *S. caerulescens* contributed 15.63% of the dissimilarity between AP and NC-AP, showing that artificial perches can function as places to rest or socialize, because although frequently used by *S. caerulescens,* they do not offer direct food resources to this species. The occurrence of *M. bonariensis* weighed heavily in the separation between NC and NC-AP (Fig. 5a), conferring a negative effect, because the species presents brood parasitism and uses perches to monitor the construction of host nests (Banks & Martin, 2001).

The main difference in the bird assemblage between FF and the other treatments and groups was due to the presence of forest insectivores, omnivores, and granivores. However, few studies

have investigated the role of exclusively forest insectivores in dispersal and forest restoration. Some of the insectivores recorded in this study, e.g., *Setophaga pitiayumi*, *Colaptes melanochloros,* and *Myiodynastes maculatus* are frequently recorded consuming fruits (Jesus & Monteiro-Filho, 2007; Kaminski, 2013).

Forest insectivores are naturally limited to colonizing agricultural environments and open areas due to their low mobility and specific environmental requirements (Sekercioglu, 2012). Thus, alternatives should be identified to favor colonization by this guild. According to Sheldon & Nadkarni (2013), the presence of lianas and epiphytes is crucial to attract forest insectivores in open environments. Thus, isolated trees covered by lianas are more attractive than perches for this group.

Among the forest omnivores, *T. leucomelas* was responsible for most of the dissimilarity between FF and HD. Thrushes are characterized as frugivorous omnivores with a great capacity to disperse (with quality) forest seeds (Mota-Gomes et al., 2008; Gasperin & Pizo, 2012). A similar result was obtained by Wal et al. (2012), whereby another thrush, *Turdus grayi*, contributed the most to dissimilarity between planted forests and agrosystems. This group of omnivores can carry out reasonable movements in the landscape (Cardoso-da-Silva et al., 1996). Thus, they are the most suitable candidates for the use of artificial perches, such as ecological trampolines as highlighted by Reis et al. (2007, 2010), allowing the dissemination of seeds between fragments.

The similarity between FF and HD was the highest, indicating that during the first 2 years, high-diversity planting possesses a greater capacity to attract forest species. This pattern was confirmed by SIMPER analysis, indicating lower dissimilarity between the forest fragment and high-diversity planting. Thus, the use of rapid-growth pioneer species in HD probably brings about a shaded environment, which reduces the proliferation of grasses (Carvalho et al., 1995). In this way, the number of open-area granivores will decrease (Vickery et al., 2002; Fuller, 2012). The planting of slow-growing species helps to form a precocious stratification between pioneer and non-pioneer species in HD. This should favor insectivores over the long term, because of the increase in different leaf strata (Willson, 1974; Marzluff & Ewing, 2001).

If with the succession, the tendency of attractiveness for forest species were maintained in HD, high-diversity planting would probably reach (in less time) characteristics of an environment in the late primary stage of ecological succession, leading to a more adequate environment for the maintenance of bird species dependent on the forest, and, thus, supporting conservation efforts (Lindell et al., 2012; Reid et al., 2012).

The low similarity between experimental treatments, in relation to the source fragment suggests that colonization during the first 2 years is by mobile species that occur at the edges of adjacent plantations and farms, emphasizing the importance of these sites as sources of colonizer species (Vickery et al., 2002; Sekercioglu, 2012). According to Haslem & Bennett (2008) and Herzon et al. (2014), the capacity to colonize new environments is related to species abundance in the source areas. In the present study, each species was recorded once, indicating that FF is also restrictive in the maintenance of specialized frugivores, limiting colonization processes in other areas.

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Appendix 1. List of species. Values obtained by means of similarity of percentages (SIMPER) analysis carried out for the total dissimilarity between treatments and artificial groups. The guilds (α+β) use codes composed of diet (first letter) and main habitat (following two letters): insectivorous (I), omnivorous (O), frugivorous (F), granivorous (G), nectarivorous (N), carnivorous (C); open area (OA), forest (FO), edge (ED).

Family/Taxon CBRO (2015)	Dissimilarity Total	Contribution %	Cumulative %	Mean abundance (SIMPER; treatments/groups) FF	NC	PR	HD	NC-AP	AP	Guilds α+β
Thraupidae: *Volatinia jacarina* (Linnaeus, 1766)	9.05	13.33	13.33	0	64.3	66.5	9.5	61.3	1.5	GOA
Thraupidae: *Coriphospingus cucullatus* (Statius Muller, 1776)	8.06	11.86	25.19	1	62.8	56.8	19.3	55.3	7	GED
Thraupidae: *Sporophila caerulescens* (Vieillot, 1823)	6.92	10.18	35.37	0.25	60.8	45.8	5.25	39.5	12.8	GOA
Columbidae: *Columbina talpacoti* (Temminck, 1811)	4.08	6.008	41.38	1.5	48.5	20.3	12.8	23.8	19.5	GOA
Columbidae: *Leptotila verreauxi* Bonaparte, 1855	2.45	3.599	44.97	21.3	3.5	1.25	13.8	3.75	0	GFO
Turdidae: *Turdus leucomelas* Vieillot, 1818	2.23	3.279	48.25	28.5	1.25	1	1.75	1	0	OFO
Fringillidae: *Spinus magellanica* (Vieillot, 1805)	2.06	3.035	51.29	0	15.8	9.5	2.25	2.75	12.5	GOA
Parulidae: *Geothlypis aequinoctialis* (Gmelin, 1789)	1.99	2.922	54.21	0	13	13.8	6	12.3	0.25	IED
Parulidae: *Basileuterus culicivorus* (Deppe, 1830)	1.90	2.8	57.01	25.5	0	0	0	0	0	IFO
Parulidae: *Myiothlypis leucoblephara* (Vieillot, 1817)	1.72	2.537	59.55	23.3	0	0	0	0	0	IFO
Tyrannidae: *Tyrannus melancholicus* Vieillot, 1819	1.62	2.391	61.94	0	13	0.5	1.75	0.75	11.8	IOA
Cuculidae: *Crotophaga ani* Linnaeus, 1758	1.46	2.146	64.08	0	14.5	7.25	1.75	5.5	6.5	IOA
Thraupidae: *Sicalis flaveola* (Linnaeus, 1766)	1.37	2.015	66.1	0.5	10.8	0.25	1.75	1	9.25	GOA
Troglodytidae: *Troglodytes musculus* Naumann, 1823	1.21	1.776	67.88	0	9.25	7	4.25	8	1.5	IOA
Columbidae: *Patagioenas picazuro* (Temminck, 1813)	1.03	1.517	69.39	12.8	0.5	0	1	0.5	0	GED
Turdidae: *Turdus amaurochalinus* Cabanis, 1850	1.02	1.507	70.9	6.25	8	4.25	4.75	4.75	2	OFO

Parulidae: *Setophaga pitiayumi* (Vieillot, 1817)	0.98	1.441	72.34	13.5	0	0	0	0	0	IFO
Trochilidae: *Chlorostilbon lucidus* (Shaw, 1812)	0.96	1.413	73.75	0.75	6.5	1.25	7.25	3	2.5	NOA
Cardinalidae: *Habia rubica* (Vieillot, 1817)	0.93	1.366	75.12	12	0	0	0	0	0	OFO
Thraupidae: *Embernagra platensis* (Gmelin, 1789)	0.92	1.356	76.48	0	7	1.5	2.5	5.25	1.5	GOA
Thraupidae: *Saltator similis* d'Orbigny & Lafresnaye, 1837	0.92	1.353	77.83	7.5	5	4.75	0.75	5	0.5	OFO
Tyrannidae: *Tyrannus savana* Vieillot, 1808	0.91	1.345	79.17	1.5	7.25	0.25	3.5	0.75	5.25	IOA
Tyrannidae: *Pitangus sulphuratus* (Linnaeus, 1766)	0.88	1.289	80.46	5.25	7.25	1.75	1.75	1	4.75	OOA
Furnariidae: *Synallaxis spixi* Sclater, 1856	0.81	1.191	81.65	0	3.5	6.5	0.25	3.25	0	IED
Thraupidae: *Tachyphonus coronatus* (Vieillot, 1822)	0.50	0.7329	82.39	2.5	2	3.25	0.5	2.25	0	OFO
Cuculidae: *Guira guira* (Gmelin, 1788)	0.48	0.7025	83.09	0	0.25	1.5	3.25	0.25	0.5	IOA
Columbidae: *Leptotila rufaxilla* (Richard & Bernard, 1792)	0.47	0.6982	83.79	6	0	0	0	0	0	GFO
Turdidae: *Turdus rufiventris* Vieillot, 1818	0.47	0.6897	84.48	4.5	0.5	0	1.5	0.25	0.25	OFO
Tyrannidae: *Serpophaga subcristata* (Vieillot, 1817)	0.43	0.6297	85.11	0	2.5	3	1	2.25	0	IOA
Thraupidae: *Conirostrum speciosum* (Temminck, 1824)	0.42	0.6164	85.72	3.75	0.5	1.25	0.5	0	0.5	IFO
Thraupidae: *Trichothraupis melanops* (Vieillot, 1818)	0.38	0.5628	86.29	5	0	0.25	0	0	0	OFO
Furnariidae: *Synallaxis cinerascens* Temminck, 1823	0.37	0.5474	86.83	5.25	0	0	0	0	0	IED
Thamnophilidae: *Thamnophilus ruficapillus* Vieillot, 1816	0.37	0.5427	87.38	0.25	2.5	2.75	0.75	2.25	0	IOA
Furnariidae: *Lochmias nematura* (Lichtenstein, 1823)	0.35	0.5086	87.88	4.5	0	0	0	0	0	IFO
Tyrannidae: *Lathrotriccus euleri* (Cabanis, 1868)	0.34	0.5054	88.39	5	0	0	0	0	0	IFO
Columbidae: *Zenaida auriculata* (Des Murs, 1847)	0.33	0.4893	88.88	0.5	2.75	0.5	0.5	0.25	2.25	GOA
Icteridae: *Agelaioides badius* (Vieillot, 1819)	0.32	0.4751	89.35	0	2.75	0	0	2	0.75	GOA
Momotidae: *Baryphthengus ruficapillus* (Vieillot, 1818)	0.30	0.4465	89.8	3.75	0	0	0	0	0	IFO
Thraupidae: *Tersina viridis* (Illiger, 1811)	0.29	0.4248	90.23	2	0.25	0	1.25	0	0	FED
Thraupidae: *Sicalis luteola* (Sparrman, 1789)	0.28	0.4053	90.63	0	1	1.75	1	1	0.25	GOA
Icteridae: *Molothrus bonariensis* (Gmelin, 1789)	0.27	0.3945	91.03	0	2	0.5	0	0.25	1.75	GOA
Tyrannidae: *Myiophobus fasciatus* (Statius Muller, 1776)	0.26	0.384	91.41	0.25	1.75	1.5	0	1.5	0	IOA
Furnariidae: *Furnarius rufus* (Gmelin, 1788)	0.26	0.3836	91.79	0	1.75	1	0	0.25	1.5	IOA
Trochilidae: *Phaethornis pretrei* (Lesson & Delattre, 1839)	0.26	0.3786	92.17	3.25	0	0.25	0	0	0	NED
Tyrannidae: *Myiodynastes maculatus* (Statius Muller, 1776)	0.24	0.3585	92.53	3.5	0	0	0	0	0	IFO
Mimidae: *Mimus saturninus* (Lichtenstein, 1823)	0.24	0.3488	92.88	0	1	0	0.25	0	2	OOA
Cuculidae: *Piaya cayana* (Linnaeus, 1766)	0.22	0.3287	93.21	3	0	0	0	0	0	IED
Icteridae: *Cacicus haemorrhous* (Linnaeus, 1766)	0.22	0.3218	93.53	3	0	0	0	0	0	OED

Species										
Turdidae: *Turdus albicollis* Vieillot, 1818	0.22	0.3176	93.85	2.75	0	0	0	0	0	OFO
Accipitridae: *Rupornis magnirostris* (Gmelin, 1788)	0.21	0.3154	94.16	1.5	1	0.25	0	0	1	COA
Passerellidae: *Ammodramus humeralis* (Bosc, 1792)	0.20	0.3009	94.46	0	2	0	0	1.75	0	GOA
Thraupidae: *Tangara sayaca* (Linnaeus, 1766)	0.20	0.2928	94.76	1.25	1	0.25	0	0.75	0.25	OFO
Rynchocyclidae: *Leptopogon amaurocephalus* Tschudi, 1846	0.20	0.2875	95.04	2.75	0	0	0	0	0	IFO
Tyrannidae: *Elaenia flavogaster* (Thunberg, 1822)	0.18	0.2634	95.31	0	1.5	0	0.5	1	0.25	OED
Rynchocyclidae: *Myiornis auriculares* (Vieillot, 1818)	0.18	0.2607	95.57	0	0.5	1.75	0	0.5	0	IED
Furnariidae: *Synallaxis ruficapilla* Vieillot, 1819	0.17	0.2547	95.82	2.25	0	0	0	0	0	IED
Accipitridae: *Elanus leucurus* (Vieillot, 1818)	0.17	0.2533	96.08	0	1	0	0.5	0.25	0.75	COA
Cardinalidae: *Cyanoloxia brissonii* (Lichtenstein, 1823)	0.17	0.2502	96.33	0	0.5	1.25	0.25	0.75	0	GOA
Picidae: *Colaptes melanochloros* (Gmelin, 1788)	0.17	0.2496	96.58	0	0.25	0	1.5	0	0.25	IED
Tyrannidae: *Empidonomus varius* (Vieillot, 1818)	0.16	0.2303	96.81	0.25	1	0	0	0	1	IOA
Hirundinidae: *Progne tapera* (Vieillot, 1817)	0.15	0.2207	97.03	0	0.75	0.5	0.5	0.75	0	IOA
Tyrannidae: *Camptostoma obsoletum* (Temminck, 1824)	0.15	0.2138	97.24	0.5	1	0.5	0	0.5	0	IOA
Rynchocyclidae: *Phylloscartes ventralis* (Temminck, 1824)	0.14	0.2017	97.44	1.75	0	0	0	0	0	IFO
Tyrannidae: *Megarynchus pitangua* (Linnaeus, 1766)	0.13	0.1976	97.64	1	0.5	0	0	0	0.5	OED
Cracidae: *Penelope superciliaris* Temminck, 1815	0.13	0.1893	97.83	2	0	0	0	0	0	OFO
Rallidae: *Aramides saracura* (Spix, 1825)	0.12	0.1782	98.01	1.25	0	0	0.25	0	0	OFO
Thraupidae: *Pipraeidea melanonota* (Vieillot, 1819)	0.11	0.1692	98.18	1.5	0	0	0	0	0	OFO
Thamnophilidae: *Thamnophilus caerulescens* Vieillot, 1816	0.11	0.1686	98.34	1.75	0	0	0	0	0	IFO
Picidae: *Picumnus temminckii* Lafresnaye, 1845	0.11	0.168	98.51	1.25	0	0.5	0	0	0	IED
Trogonidae: *Trogon surrucura* Vieillot, 1817	0.10	0.1504	98.66	1.25	0	0	0	0	0	OFO
Tyrannidae: *Euscarthmus meloryphus* Wied, 1831	0.10	0.1407	98.8	1.25	0	0	0	0	0	IFO
Cuculidae: *Coccyzus melacoryphus* Vieillot, 1817	0.09	0.1256	98.93	0	0.25	0	0.5	0.25	0	IED
Corvidae: *Cyanocorax chrysops* (Vieillot, 1818)	0.08	0.1241	99.05	1.25	0	0	0	0	0	OED
Cuculidae: *Tapera naevia* (Linnaeus, 1766)	0.08	0.1214	99.17	0.25	0	1	0	0	0	IED
Turdidae: *Turdus subalaris* (Seebohm, 1887)	0.08	0.12	99.29	1	0	0	0	0	0	OFO
Cardinalidae: *Cyanoloxia glaucocaerulea* (d'Orbigny & Lafresnaye, 1837)	0.07	0.1063	99.4	1	0	0	0	0	0	GED
Tinamidae: *Crypturellus parvirostris* (Wagler, 1827)	0.07	0.1057	99.51	0.5	0.25	0	0.25	0.25	0	OFO
Caprimulgidae: *Hydropsalis albicollis* (Gmelin, 1789)	0.07	0.1009	99.61	0	0	0	0.75	0	0	IED
Conopophagidae: *Conopophaga lineata* (Wied, 1831)	0.06	0.09466	99.7	1	0	0	0	0	0	IFO
Strigidae: *Athene cunicularia* Molina, 1782)	0.05	0.06822	99.77	0	0	0	0.5	0	0	COA

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Families/Species	Dissimilarity	Total	Total	Total of Contacts						Guilds
Falconidae: *Milvago chimachima* (Vieillot, 1816)	0.03	0.04195	99.81	0	0.25	0	0	0.25	0	COA
Thraupidae: *Sporophila nigricollis* (Vieillot, 1823)	0.02	0.0365	99.85	0	0	0.5	0	0	0	GOA
Pipridae: *Chiroxiphia caudata* (Shaw & Nodder, 1793)	0.02	0.02948	99.88	0.25	0	0	0	0	0	FFO
Picidae: *Veniliornis spilogaster* (Wagler, 1827)	0.02	0.02948	99.91	0.25	0	0	0	0	0	IFO
Thamnophilidae: *Mackenziaena leachii* (Such, 1825)	0.02	0.02657	99.93	0.25	0	0	0	0	0	IFO
Ramphastidae: *Pteroglossus castanotis* Gould, 1834	0.02	0.02366	99.96	0.25	0	0	0	0	0	FFO
Cathartidae: *Coragyps atratus* (Bechstein, 1793)	0.02	0.02366	99.98	0.25	0	0	0	0	0	COA
Tyrannidae: *Satrapa icterophrys* (Vieillot, 1818)	0.01	0.01825	100	0	0	0.25	0	0	0	IOA
31/88	67.93	100%	100%	993	1582	1097	467	1131	451	14

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Annex 1 (supplementary document 1). List of species used for the implementation of high-diversity planting (HD) and nucleation (NC) techniques. The nomenclature adopted for families and genera follow the Angiosperm Phylogeny Group III pattern [1]. Species identification (epithets) follows the List of Flora of Brazil, 2013 [2] and The International Plant Names Index, 2013 [3]. CT-SU means guilds: pioneer (P) and non-pioneer (NP), while CT-SI means silvicultural category based on NBL and TNC [4].

Code	Family	Species	CT-SU	CT-SI
1	Euphorbiaceae	*Croton floribundus* Spreng.	P	Filling
2	Fabaceae	*Mimosa scabrella* Benth.	P	Filling
3	Primulaceae	*Myrsine coriaceae* (Sw.) R. Br	P	diversity
4	Myrtaceae	*Psidium* cf. *cattleyanum* (Mart. ex O. Berg) Kiaersk.	NP	diversity
5	Phytolaccaceae	*Gallesia integrifolia* (Spreng.) Harms	NP	diversity
6	Myrtaceae	*Myrcianthes pungens* (O.Berg) D.Legrand	NP	diversity
7	Aquifoliaceae	*Ilex paraguariensis* A.St.-Hil.	NP	diversity
8	Laminaceae	*Vitex megapotamica* (Spreng.) Moldenke	NP	diversity
11	Cannabaceae	*Trema micrantha* (L.) Blume	P	filling
12	Annonaceae	*Annona cacans* Warm.	P	diversity
15	Caricaceae	*Jaracatia spinosa* (Aubl.) DC.	NP	diversity
16	Euphorbiaceae	cf. *Croton urucurana* Baill.	P	diversity
18	Sterculiaceae	*Guazuma ulmifolia* Lam.	P	filling
19	Fabaceae	*Piptadenia gonoacantha* (Mart.) J.F. Macbr.	NP	filling
23	Loganiaceae	*Strychnos brasiliensis* (Spreng.) Mart.	NP	diversity
24	Fabaceae	*Machaerium stipitatum* (DC.) Vogel	NP	diversity
25	Rosaceae	*Prunus myrtifolia* (L.) Urb.	NP	diversity
26	Rubiaceae	*Randia ferox* (Cham. & Schltdl.) DC.	P	diversity
27	Sapindaceae	*Allophyllus edulis* (A.St.-Hil., Cambess. & A. Juss.) Radlk.	P	diversity
28	Fabaceae	*Cassia leptophylla* Vogel.	NP	diversity
29	Lauraceae	*Ocotea porosa* (Nees) Barroso	NP	diversity
30	Elaeocarpaceae	*Sloanea monosperma* Vell.	NP	diversity
31	Cannabaceae	*Celtis* cf. *iguanaea* (Jacq.) Sargent	P	diversity
32	Lythraceae	*Lafoensia pacari* A.St.-Hil	NP	diversity
33	Primulaceae	*Myrsine umbellata* Mart.	NP	diversity
34	Euphorbiaceae	*Alchornea sidifolia* Müll.Arg.	NP	filling
35	Myrtaceae	*Campomanesia xanthocarpa* O.Berg	NP	diversity
36	Fabaceae	*Inga vera* Willd.	NP	diversity
37	Bignoniaceae	*Jacaranda micrantha* Cham.	NP	diversity
38	Asteraceae	*Moquiniastrum polymorpha* (Less.) Cabr.	P	diversity
39	Meliaceae	*Cabralea canjarana* (Vell) Mart	NP	diversity
40	Lauraceae	*Ocotea puberula* (Rich.) Ness	NP	diversity
41	Fabaceae	*Calliandra tweedii* Benth.	P	diversity
42	Podocarpaceae	*Podocarpus lambertii* Klotzsch	T	diversity
44	Canellaceae	*Cinnamodendron dinisii* Schwacke	NP	diversity
45	Salicaceae	*Xylosma* sp.	P	diversity
47	Euphorbiaceae	*Sebastiania commersoniana* (Baill.) L.B. Sm. & Downs	P	diversity
48	Boraginaceae	*Cordia americana* (L.) Gottshling & J.E.Mill.	NP	diversity

50	Euphorbiaceae	*Sebastiania schottiana* (Müll.Arg.) Müll.Arg.	NP	diversity
53	Myrtaceae	*Campomanesia guazumifolia* (Cambess.) O.Berg.	NP	diversity
54	Sapindaceae	*Cupania vernalis* Cambess.	NP	diversity
55	Meliaceae	*Cedrela fissilis* Vellozo	NP	diversity
56	Malvaceae	*Ceiba speciosa* (A. St.-Hil.) Ravenna	NP	diversity
57	Bignoniaceae	*Handroanthus chrysotrichus* (Mart. ex A.DC.) Mattos	NP	diversity
58	Rutaceae	*Zanthoxylum rhoifolium* Lam.	NP	diversity
58	Rutaceae	*Balfourodendron riedelianum* (Engl.) Engl.	NP	diversity
59	Anacardiaceae	*Schinus terebinthifolius* Raddi	P	filling
60	Moraceae	*Ficus enormis* (Mart. ex Miq.) Mart.	P	diversity
63	Fabaceae	*Peltophorum dubium* (Spreng.) Taub.	P	diversity
64	Fabaceae	*Lonchocarpus* sp.	-	diversity
66	Sapindaceae	*Diatenopteryx sorbifolia* Radlk.	P	diversity
67	Fabaceae	*Erythrina falcata* Benth.	NP	diversity
68	Fabaceae	*Bauhinia forficata* Link	NP	filling
69	Salicaceae	*Casearia decandra* Jacq.	NP	diversity
72	Meliaceae	*Trichilia claussenii* C. DC.	NP	diversity
73	Myrtaceae	cf. *Myrceugenia euosma* (O.Berg) D. Legrand	NP	diversity
74	Myrtaceae	*Eugenia pyriformis* Cambess.	NP	diversity
75	Myrtaceae	*Eugenia uniflora* L.	NP	diversity
76	Myrtaceae	*Eugenia involucrata* DC.	NP	diversity
77	Myrtaceae	*Plinia peruviana* (Poir.) Govaerts	NP	diversity
79	Solanaceae	*Solanum* cf. *bullatum* Vell.	P	filling
101	Apocynaceae	*Aspidosperma polyneuron* Müll.Arg.	NP	diversity
103	Fabaceae	*Albizia polycephala* (Benth.) Killip	P	diversity
104	Araucariaceae	*Araucaria angustifolia* (Bertol.) Kuntze	NP	diversity
110	Fabaceae	*Parapiptadenia rigida* (Benth.) Brenan	NP	diversity
120	Fabaceae	*Mimosa bimucronata* (DC.) Kuntze	P	diversity
121	Arecaceae	*Butia capitata* (Mart.) Becc.	NP	diversity
122	Celastraceae	*Maytenus aquifolia* Mart.	NP	diversity
123	Polygonaceae	*Ruprechtia laxiflora* Meisn.	NP	diversity
124	Arecaceae	*Syagrus romanzoffiana* (Cham.) Glassman	NP	diversity
125	Fabaceae	*Enterolobium contortisiliquum* (Vell.) Morong	NP	filling

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