

COMMUNITY SIMILARITY AND ABUNDANCE OF BIRD SPECIES IN OPEN HABITATS OF A CENTRAL BRAZILIAN CERRADO

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Resumo. – **Similidade entre comunidades e abundância de espécies de aves em habitats abertos de cerrado no Brasil central.** – Fisionomias abertas ocupam uma grande extensão do cerrado e têm sido intensamente destruídas por uma agricultura mecanizada em larga escala. Este trabalho teve como objetivo examinar a abundância de espécies de aves neste gradiente de fisionomias a fim de verificar a similaridade entre as comunidades. Aves foram contadas pelo método de pontos e a vegetação medida em áreas de cerrado *sensu stricto* (n = 3), campo cerrado (n = 2), campo sujo (n = 2) e campo limpo (n = 1). Um total de 110 espécies foram registradas durante 238 amostragens de 20 minutos em 58 pontos. Mudanças nas comunidades de aves covariaram significativamente com mudanças na estrutura da vegetação, ao longo do gradiente. Foram observadas correlações significativas entre variáveis da estrutura da vegetação e a abundância de determinadas espécies. Por exemplo, além de ter associação positiva com o aumento da riqueza e abundância de espécies arbóricolas, o aumento da densidade de árvores teve correlação com a diminuição da abundância e ausência de certas espécies que utilizam o estrato herbáceo. Comunidades de campo limpo e campo sujo apresentaram relativamente poucas espécies, mas entre elas encontraram-se espécies raras e endêmicas. Noventa e cinco por cento das espécies de campo limpo ocorreram nos campos sujos, a maioria delas com abundâncias comparáveis. Estes habitats diferiram principalmente pelo acréscimo de espécies que usam o estrato arbustivo e arbóreo nos campos sujos. A avifauna de campo cerrado apresentou maior porcentagem e abundância de espécies arbóricolas, mas manteve uma porção considerável das espécies de campos. Suas avifaunas foram mais similares às de cerrado *sensu stricto* do que às de campo sujo. A riqueza e abundância de espécies arbóricolas foram maiores nos cerrados *sensu stricto*, onde espécies abundantes em campos foram ausentes ou pouco numerosas.

Abstract. – Open habitats occupy a large extension in the cerrado region and have been intensively destroyed by large scale mechanized agriculture. This study aimed to examine bird species abundance within this open habitat gradient to verify similarity among communities. Birds were surveyed by point counts and vegetation measured in cerrado *sensu stricto* (n = 3), campo cerrado (n = 2), campo sujo (n = 2) and campo limpo (n = 1) stands. A total of 110 species were recorded during 238 samples of 20 min at 58 points. Changes in bird communities covaried significantly with changes in vegetation structure along the gradient. Significant correlations between structural variables and abundance of some species were observed. For example, tree density had positive correlation with richness and abundance of arboreal bird species, and negative correlation with richness and abundance of some birds that use the herbaceous stratum. Campo limpo and campo sujo communities contained relatively fewer species, but included rare and endemic species. Ninety-five percent of campo limpo species occurred in campos sujos, most of them with comparable abundances. These two habitats differed mainly due to the further increase of species that use shrubs and trees in campo sujo. The campo cerrado avifauna presented greater percentage and abundance of arboreal species, but maintained a considerable portion of the grassland species. Their communities

were more similar to those of cerrado *sensu stricto* than to those of campo sujo. The richness and abundance of arboreal species presented highest values in the cerrado *sensu stricto* stands, where grassland species were absent or occurred in low numbers. *Accepted 29 May 2000.*

Key words: *Bird community, cerrado, savanna, open habitats, grasslands, bird-habitat relationship, Neotropical, Brazil.*

INTRODUCTION

Bird species respond differently to distinct environmental factors (Rotenberry & Wiens 1980, Bibby *et al.* 1985, MacNally 1990), occasioning strong associations between communities and particular habitats (Kikkawa 1982, Cody 1985, Woinarski *et al.* 1988). The understanding of these relationships provides information on the impact of habitat disturbance on populations, especially in intensively explored regions.

The cerrado is the largest South American savanna formation, occupying an area of about 1.8 million km² (Ab' Saber 1977, Sarmiento 1983), and occurs as the dominant vegetation in the highlands of central Brazil, extending through peninsulas and disjunct patches to the adjacent vegetation provinces of chaco, caatinga and Atlantic and Amazon forests (Eiten 1993). The cerrado occurs as a mosaic of several habitats, like that of cerrado *sensu lato*, mesophytic and gallery forests and marshes. The cerrado *sensu lato* includes a forest (the cerradão) and 4 open habitats: cerrado *sensu stricto*, campo cerrado, campo sujo and campo limpo (Eiten 1993).

This diversified landscape in cerrado presents a rich avifauna of approximately 840 species with an endemism level of 3.8% (Silva 1995). A strongly seasonal rainfall regime (Eiten 1993) and the patchy distribution of habitats favors movements of some species among habitats to obtain seasonally available resources (Cavalcanti 1992, Lins 1994). Among the 759 resident bird species in the cerrado region, 208 (27.4%) are restricted to open habitats (that of cerrado *sensu lato*, *brejos* and campos *rupestres*), and other 158 (20.8%)

occurs both in forested and open habitats (Silva 1995), indicating that open habitats contain almost half of the total resident species of cerrado. Despite having lower richness than the gallery forests, the campo grassland, campo cerrado and cerrado *sensu stricto* are used by half of the 41 endemic cerrado birds, of which 9 are restricted to these open habitats (Stotz *et al.* 1996).

Several studies provide data on distribution of bird species in cerrado habitats (Sick 1965, Fry 1970, Willis & Oniki 1991, Bates *et al.* 1992, Silva 1995, Stotz *et al.* 1996, Bagno 1998). There is data on abundances for cerrado *sensu stricto* (Negret 1983, Lins 1994), campo sujo (Figueiredo 1991) and campo limpo (Negret 1983). However, no study has been done on communities in campo cerrado, despite it is considered distinct from a vegetation viewpoint (Eiten 1993).

This study aimed to examine the presence and abundance of bird species by the four open habitats of cerrado *sensu lato*, verifying the similarity among their communities.

STUDY AREA AND METHODS

Study area. This study was conducted in the “Estação Ecológica do Jardim Botânico de Brasília” (15°55'S, 47°52'W) and at “Fazenda Água Limpa” of Universidade de Brasília (15°57'S, 47°55'W), both situated in Distrito Federal, Brazil. They represent a 10.000 ha continuous landscape in the central region of cerrado highlands and present preserved tracts of the main habitats of this biome. The regional climate is Aw according to the Köppen climatic classification. There is a strongly seasonal rainy period with a dry season

TABLE 1. Study sites, with their area, number of bird count points (NP), number of bird samplings per point (S/P), total number of samplings (TS) and number of points with vegetation sampling (NV).

Study sites	Area (ha)	NP	S/P	TS	NV
Cerrado sensu stricto (SS1)	180	12	3	36	6
Cerrado sensu stricto (SS2)	200	12	3	36	6
Cerrado sensu stricto (SS3)	45	12	3	36	6
Campo cerrado (CC1)	95	6	5	30	6
Campo cerrado (CC2)	40	4	5	20	4
Campo sujo (CS1)	35	4	6	24	4
Campo sujo (CS2)	40	4	6	24	4
Campo limpo (CL1)	55	4	8	32	4

between May and September (Eiten 1993). Additional general information of the region can be found in Pinto (1993).

The cerrado *sensu lato* originally covered 85% of the cerrado region and represents a gradient of physiognomic forms dependent on substrate aspects and periodic fires (Eiten 1993). We adopted Eiten's (1993) division of cerrado *sensu lato* which is based on the density of the woody layer: cerradão, cerrado *sensu stricto*, campo cerrado, campo sujo and campo limpo. The first is a forest, while the others are open habitats that are briefly described below.

The cerrado *sensu stricto* (SS) is the dominant physiognomy in this province and presents trees with 3 m or more in height which promote a cover of 10 to 30%, not forming a continuous canopy. In few cases, trees may promote a cover of 60% (Eiten 1993).

The campo cerrado (CC) is dominated by the shrub and herbaceous layers, with a few sparse trees from 2 to 5 m in height, and tree cover in the 2 to 15% range (Ribeiro *et al.* 1983, Sarmiento 1983).

The campo sujo (CS) has an almost continuous herbaceous layer, with tree and shrubs sparsely distributed with less than 2% cover, being mostly less developed individuals of cerrado *sensu stricto* tree species (Ribeiro

et al. 1983, Sarmiento 1983).

The campo limpo (CL) has only the herbaceous layer, with occasional shrubs that do not grow higher than the surrounding vegetation (Eiten 1993, Sarmiento 1983).

We selected 8 study sites representing these 4 open habitats (Table 1). Replicates of each habitat were selected when possible to test differences between communities of a same habitat. In each site, birds were surveyed and vegetation was sampled.

Bird surveys. Bird surveys were conducted from June 1995 to April 1996 by D. P. Tubelis at 58 stations (i.e., points) distributed through the study sites. The variable circular plot census method (Reynolds *et al.* 1980) was conducted between sunrise and 07:30 h, when detection rates declined substantially. During a 20-min period, the observer recorded each individual bird detected by sight or sound. Birds clearly outside the habitat in which the point was located were excluded. Sampling started immediately after the observer arrived at each point. Two to three distinct points were surveyed each day. The daily order of point sampling was changed to eliminate time-of-day morning bias. Rainy or windy mornings were avoided. For gregarious species like *Cyanocorax cristatellus* and *Phacellodomus*

rufifrons, we assumed groups heard but not seen had the mean group size for that species.

Points were located in the center of each habitat (at least 200 m from the edge) to minimize the probability in recording birds from other habitats, except in SS3, where this distance was 100m. Points were located at least 200 m from roads to avoid disturbance by traffic and to diminish the probability in recording birds that use exotic grasses growing along the roads. Points were spaced about 200 m apart to increase the probability of sample independence. The number of points per site varied according to patch size and vegetation structure. In each habitat, all points were sampled for the same number of times (Table 1).

Distinction of voices in two genus was uncertain. *Elaenia* spp. probably contained records of *Elaenia parvirostris*, *E. albiceps* and unidentified voices of other *Elaenia* species present in the Appendix. Further, *Myiarchus* spp. contained records of undistinguished short vocalizations of all *Myiarchus* species recorded in this study.

Habitat measures. The vegetation sampling was conducted during March and April 1996 in 40 points of bird counting (Table 1). We selected 8 structural variables expected to affect the presence of bird species. In each point, 3 equidistant bands or transects, measuring 60 m in length and 4 m in width, were lined apart from the point in which the observer conducted bird counts. The cover of trees, shrubs and herbs was estimated by the line-intercept sampling method (Brower & Zar 1984). The densities of trees and shrubs were estimated by counting all individuals in the bands. The height of the herbaceous stratum was measured each 5 m along the 60-m line. All shrubs and trees situated in the 240 m² bands had their heights taken, except in the sites of cerrado *sensu stricto*, where only the trees and shrubs intercepted by the line were measured.

This classification was used to separate the vegetation stratum: herbs (plants with stem circumference less than 3 cm, measured at 0.1 m height), trees (woody plants 3 m or higher, or with stem circumference larger than 10 cm at 1.5 m height) and shrubs (plants larger than herbs and smaller than trees). Two shrubs were considered distinct individuals when the distance between their foliage was greater than 50 cm. For trees, this distance was 2 m.

Data analysis. Species abundances of bird species were adjusted to a common scale, since sampling effort varied among sites. Thus, the relative abundance of species refers to the mean number of individuals recorded per 20-min sample in any study site.

A principal component analysis (PCA) on a covariance matrix was used to determine which bird species contributed most to variation among communities. Site SS3 was not included in this PCA; all species of the other sites were included in this analysis.

The Mantel test, a pair-wise statistical comparison of data matrices, was used to verify if differences in bird communities (matrix of relative abundance) covary significantly with differences in vegetation structure. We used Mantel's asymptotic approximation (Douglas & Endler 1982). The distance measure was Sorensen's, using the package PCORD, Version 3.20.

A chi-squared test was used to test differences between grassland habitats (CL+CS) and habitats with denser woody layer (CC+SS1+SS2) in relation to the frequency of occurrence of bird species. For this test, each 20-min counting period was considered a sample, and only the species present in 10 or more samples were included in this analysis.

A canonical correlation was used to test relations between the set of 8 vegetation variables and the set of bird species. For this anal-

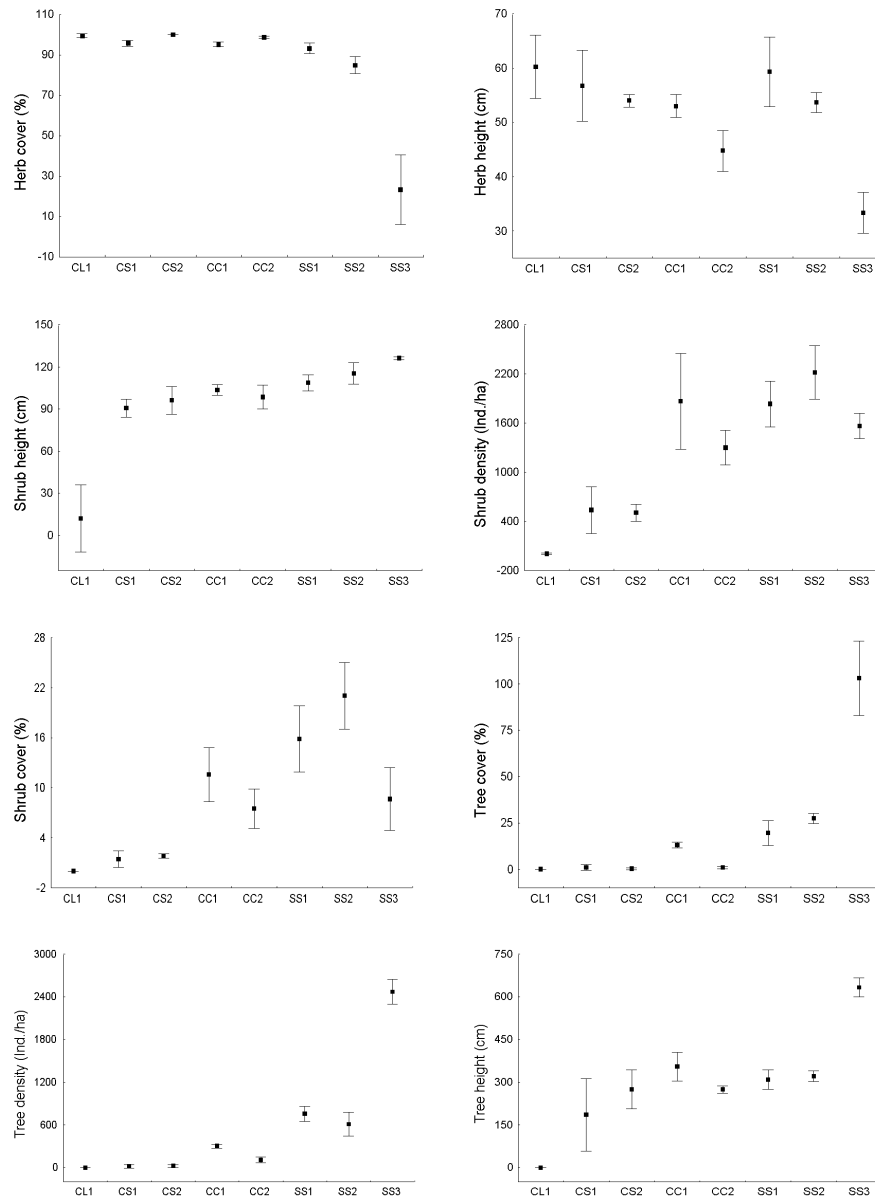


FIG. 1. Mean values of the variables of vegetation structure measured in the study sites. CL = campo limpo, CS = campo sujo, CC = campo cerrado, SS = cerrado *sensu stricto*. Numbers after each class represent site.

ysis, the relative abundances of species in each one of the 40 points with vegetation sampling were used. Only the 12 most abun-

dant species in all sites were included in the analysis because the number of variables (structural + bird species) must not be

TABLE 2. Total number of species (T), number of species present in 1, 2, 3 and 4 habitats (1H, 2H, 3H and 4H, respectively), with percentage within parentheses, and the total number of endemic species, with number of habitat-restricted species within parentheses, in open habitats of cerrado sensu lato.

Habitats	T	1H	2H	3H	4H	EN
CL	19	1 (5)	6 (32)	4 (21)	8 (42)	1 (0)
CS	38	7 (18)	10 (26)	13 (34)	8 (22)	4 (1)
CC	56	5 (9)	30 (54)	13 (23)	8 (14)	5 (0)
SS	84	39 (46)	28 (33)	9 (11)	8 (10)	5 (1)
All	110	52 (47)	37 (34)	13 (12)	8 (7)	8 (2)

TABLE 3. Values of the Jaccard's similarity index for communities of cerrado sensu lato in Brasília, DF.

	CL	CS	CC	SS	SS3
CL	1.000	0.462	0.190	0.131	0.042
CS		1.000	0.343	0.239	0.068
CC			1.000	0.683	0.231
SS				1.000	0.262
SS3					1.000

greater than the half of number of points.

RESULTS

Vegetation. The herbaceous stratum was very similar in all sites, except in SS3 where cover was less and herbs were lower. The density of shrubs tended to increase from CL to SS. However, there was a drop in the SS3 site. Similarly, the height of shrubs, tree density, and tree cover all increased from CL to SS, consistent with the vegetation characteristics of these different habitats. The campo limpo was distinguished from other plots mainly due to the absence of trees and the low abundance of shrubs. The two sites of campo sujo were very similar, while the replicates of campo cerrado differed mainly in relation to tree cover and density. The plot SS3 was distinguished from other cerrados *sensu stricto*,

primarily because it contained very tall and abundant trees, and a discontinuous herbaceous stratum (Fig. 1).

Distribution of bird species. A total of 110 species and 5755 individuals were recorded during 238 point counts. Habitats with denser woody layers had more bird species (Table 2). Eight of the 18 cerrado endemic species which occur in Distrito Federal (Negret *et al.* 1984, Cavalcanti 1988, Silva 1995) were recorded (Table 2). Five occurred in two habitats, while *Amazona xanthops* was the only species found in 3 habitats. Two species, *Porphyrospiza caerule-scens* and *Saltator atricollis*, were restricted to a single habitat. Not a single endemic species was found in all 4 habitats. Two pairs of habitats, CS-CC and CC-SS, contained 7 of 8 endemic species (Appendix).

Of the recorded species, 20% were generalists (occurring in 3 or 4 habitats) and 80% were specialists (occurring in 1 or 2 habitats). The percentage of generalist birds was greater in CL and CS than in CC and SS, in which the percentage of specialist species was greater (Table 2). cerrado *sensu stricto* contained the greatest percentage of habitat restricted species, while the greatest percentage of species occurring in the 4 habitats was found in CL. This pattern occurred because a considerable portion of species using the herbaceous stratum were common to all 4 habitats. Arboreal

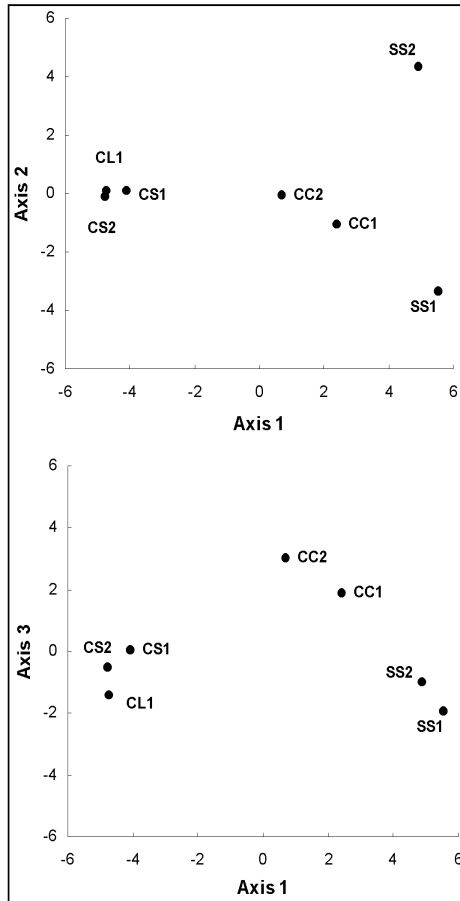


FIG. 2. First three axes of a PCA ordination of cerrado *sensu lato* bird communities. CL = campo limpo, CS = campo sujo, CC = campo cerrado, SS = cerrado *sensu stricto*. Numbers after each class represent site.

species were restricted mainly to SS. Also, the species that occurred in 2 or 3 habitats always used habitats with great structural similarity (Appendix). As a result, elevated percentages of these species were found in CC and CS, habitats that are structurally in the middle of the cerrado *sensu lato* gradient.

Similarity among the bird communities. The similarity of species composition between habi-

tats indicates that there was a tendency for similar habitats to present similar species composition (Table 3). For example, when CL is compared to other habitats, the highest value is observed for CS, and values decrease in direction to SS3. Considering all combinations, the lowest value of similarity was observed for the pair SS3-CL, while the highest one was recorded for CC-SS. CS was more similar to CL than to CC, while the similarity between CC and SS was greater than that between CC and CS. The SS3 community was very distinct from other ones, even in comparison to the other cerrado *sensu stricto* communities.

In the campo limpo, where relatively few species were recorded, *Cistothorus platensis* was the dominant species, followed by *Emberizoides herbicola*, *Alectrurus tricolor*, *Alopocheilidon fucata* and *Culicivora candacuta*. The campo sujo had 95% of the campo limpo species, plus some species that use the shrub stratum, like *Colaptes campestris*, *Cypsnagra hirundinacea* and *Sporophila plumbea*. The campo sujo communities were more similar to that of campo limpo than to that of campo cerrado. The campo cerrado avifauna contained a higher percentage of arboreal species, which occurred in lesser abundance than in cerrados *sensu stricto*. This habitat also contained considerable richness and abundance of lower strata species. Cerrados *sensu stricto* were more similar to campos cerrados, differing primarily in that most arboreal species occurred in higher numbers, and in having several habitat restricted species. Abundant campo grassland birds were absent or occurred in low numbers.

The first 3 principal components explained together 94% of variance among communities (Table 4). The first component (PC1) had higher positive weights associated to species abundant in cerrado *sensu stricto*, such as *Cyanocorax cristatellus*, *Amazona aestiva*, *Elaenia chiriquensis*, *Phacellodomus rufifrons* and

TABLE 4. Component loadings of bird species on the three first eigenvectors of the PCA. Species with loadings larger than 0.1 on at least one component are listed.

Species	PC1	PC2	PC3
<i>Crypturellus parvirostris</i>	0.11	0.02	0.05
<i>Amazona aestiva</i>	0.36	-0.41	-0.19
<i>Colaptes campestris</i>	0.00	0.03	0.16
<i>Phacellodomus rufifrons</i>	0.23	0.76	-0.30
<i>Alectrurus tricolor</i>	-0.16	0.00	-0.13
<i>Culicivora caudacuta</i>	-0.10	-0.02	0.06
<i>Elaenia chiriquensis</i>	0.25	0.00	0.14
<i>Suiriri suiriri</i>	0.19	-0.38	-0.35
<i>Camptostoma obsoletum</i>	0.12	-0.06	-0.10
<i>Alopochelidon fucata</i>	-0.13	0.00	-0.08
<i>Cyanocorax cristatellus</i>	0.42	0.12	-0.30
<i>Cistothorus platensis</i>	-0.55	0.00	-0.52
<i>Troglodytes aedon</i>	0.15	-0.14	0.07
<i>Cypsnagra hirundinacea</i>	-0.03	-0.04	0.30
<i>Neothraupis fasciata</i>	0.18	0.21	0.23
<i>Myospiza humeralis</i>	-0.09	0.02	0.21
<i>Emberizoides berbicola</i>	-0.21	0.06	0.16
Eigenvalue	122.83	31.17	19.95
% of total variance	66.35	16.84	10.78
Cumulative percent	66.35	83.19	93.97

Suiriri suiriri; stronger negative weights were associated to species abundant in CS and CL, such as *Cistothorus platensis*, *Emberizoides berbicola*, *Alectrurus tricolor*, *Alopochelidon fucata* and *Culicivora caudacuta*. So, PC1 represents a contrast, separating more open habitats, such as campo grasslands, from the more closed, like SS1 and SS2 (Fig. 2), based primarily on the abundance of above-mentioned species.

In PC2, common species in cerrado *sensu stricto* received the highest weights, with distinct signals (Table 4). Thus, this component represents a contrast between the communi-

ties of SS1 and SS2 (Fig. 2), indicating the existence of great differences in the abundance of the common species of two of the three plots of cerrado *sensu stricto*. *Amazona aestiva*, *Suiriri suiriri* and *Troglodytes aedon* were more abundant in SS1 than in SS2, while *Phacellodomus rufifrons* and *Neothraupis fasciata* were more abundant in SS2 than in SS1.

PC3 explained 10.8% of the variance and separated campo cerrado communities from the other ones. This component gave higher positive weights to species like *Cypsnagra hirundinacea* and *Neothraupis fasciata*, which were more abundant in campo cerrado than in other habitats (Table 4). Species with higher negative weights were grassland restricted and arboreal species, more abundant in cerrado *sensu stricto* than in campo cerrado.

As the PCA was based on a variance matrix, only the most abundant species contributed to communities separation. However, other not so abundant species also were more numerous in particular habitats. The species *Speotyto cunicularia* and *Nothura maculosa* were more abundant in campo limpo than in other habitats, while *Helicactin cornuta* and *Myospiza humeralis* were more abundant in campo sujo. *Sicalis luteola*, *Cypsnagra hirundinacea* and *Sporophila plumbea* were more abundant in campo cerrado than in other communities. Several species, such as *Nystalus chacuru*, *Picooides mixtus* and *Troglodytes aedon* were more abundant in cerrado *sensu stricto*.

SS3, a very closed and high cerrado *sensu stricto*, was characterized by the (1) presence of several exclusive arboreal species like *Veniliornis passerinus* and *Thlypopsis sordida*, (2) greater abundance of some arboreal species like *Hemithraupis guira* and *Tangara cayana*, (3) absence of several species common in other cerrado *sensu stricto* stands like *Phacellodomus rufifrons*, *Elaenia chiriquensis*, *Neothraupis fasciata* and *Melanopareia torquata*, and (4) lower abundance of several species common in SS1 and SS2. Among them are arboreal birds, such as

TABLE 5. Canonical coefficients of the 20 variables (8 structural and the 12 most abundant species), correlation (r), chi-squared (χ^2) and probability (P) values, in the three first canonical variables (CV1, CV2 and CV3), resulted from a canonical correlation for 40 points of vegetation and bird sampling.

Variables	CV1	CV2	CV3
Habitat variables			
Herb cover	-0.46	0.76	-0.003
Herb height	-0.26	0.56	-0.30
Shrub density	0.87	0.25	0.37
Shrub cover	0.89	0.36	0.03
Shrub height	0.63	-0.04	0.41
Tree density	0.60	-0.76	0.05
Tree cover	0.57	-0.73	-0.008
Tree height	0.57	-0.46	0.19
Species			
<i>Rhynchotus rufescens</i>	-0.60	0.13	-0.13
<i>Crypturellus parvirostris</i>	0.47	0.58	-0.06
<i>Amazona aestiva</i>	0.40	0.19	0.003
<i>Colibri serrirostris</i>	-0.05	0.52	0.09
<i>Colaptes campestris</i>	-0.13	0.40	0.12
<i>Phacellodomus rufifrons</i>	0.61	0.48	-0.34
<i>Elaenia chiriquensis</i>	0.48	0.53	0.25
<i>Cyanocorax cristatellus</i>	0.73	0.19	0.04
<i>Cistothorus platensis</i>	-0.82	-0.05	-0.40
<i>Neothraupis fasciata</i>	0.45	0.66	-0.10
<i>Myospiza humeralis</i>	-0.68	0.38	0.17
<i>Emberizoides herbicola</i>	-0.79	0.33	0.06
Canonical correlation (r)	0.96	0.95	0.81
χ^2	241.48	167.68	97.61
Df	96	77	60
P	<0.001	<0.001	0.001

Nystalus chacurn and *Elaenia cristata*, as well as lower strata species, such as *Rhynchotus rufescens* and *Crypturellus parvirostris* (see Appendix).

The matrices of vegetation structure and of relative abundance of birds showed significant positive covariation when compared (Mantel test, $r = 0.62$, $df = \text{infinite}$, $t = 3.27$, $P = 0.001$). The covariation remained significant and similar even when SS3 was excluded from the analysis (Mantel test, $r = 0.59$, $df = \text{infinite}$, $t = 3.33$, $P < 0.001$). This indicates that increasing modifications to the structure of the cerrado *sensu lato* gradient resulted in increased changes in bird community structures.

Three canonical variables presented high correlations between the two sets of variables (Table 5). In CV1, the abundance of *Cistothorus platensis*, *Rhynchotus rufescens*, *Myospiza humeralis* and *Emberizoides herbicola* were negatively correlated with increasing cover, density and height of trees and shrubs (Table 5), where as *Phacellodomus rufifrons* and *Cyanocorax cristatellus* were positively correlated with these variables. Thus, this canonical variable shows that as the habitat became more closed and high, the abundance of arboreal species increased while that of species that depends on herbs and small shrubs decreased.

The second canonical variable indicates that the abundances of *Neothraupis fasciata*, *Crypturellus parvirostris*, *Elaenia chiriquensis* and *Colibri serrirostris* were positively correlated with herb cover and negatively correlated with tree cover and density (Table 5). This indicates that when the increase in tree cover and density was high enough to cause a considerable decrease in the herb cover, as in SS3, species common in shrub dominated habitats had lowered abundance or were absent (see Appendix). In the third canonical variable, no high coefficient was found in the set of habitat variables nor in the set of bird species (Table 5).

DISCUSSION

The 110 bird species recorded in this study

represent about 54% of the species that use open non-wetland habitats of the cerrado *sensu lato* in Distrito Federal (Negret *et al.* 1984), and 13% of all species recorded in the cerrado habitats (Silva 1995). Although the categories of habitat specialization are quite subjective and vary considerably, some comparisons can be made. In this study, 20% of all bird species were habitat generalists while 80% appeared to be habitat specialists. However, Stotz *et al.* (1996) considered habitat specialization in cerrado habitats extremely low, based on all habitats of the cerrado region, not only the open habitats of cerrado *sensu lato*. The relatively high percentage of habitat specialists we observed becomes lower if the other habitats in the region are also considered. For example, most cerrado *sensu stricto* restricted species recorded in our study also occur in gallery forest and cerradão (Negret 1983, Bagno 1998).

Within the non-wetland open habitats gradient studied, specialization appeared not restricted to only one single habitat, but occurred when two or more habitats are considered. For example, *Cistothorus platensis* and *Alectrurus tricolor* occurred in campo limpo and campo sujo; *Picoides mixtus* and *Nystalus chacuru* were recorded in campo cerrado and cerrado *sensu stricto*. However, as changes in this vegetation gradient are not abrupt, birds can be found in transitional vegetation and/or in the edges of habitats with similar structure. Also, relatively small patches presenting denser or lesser cover for the vegetation strata often occur within stands of open habitats. This patchiness can also contribute to the presence of bird species in other habitats, as recorded by other studies (Sick 1965, Fry 1970, Figueiredo 1991, Silva 1995, Bagno 1998).

Habitats with greater structural similarity tended to present more similar bird communities and such result agrees with those of previous studies (Shugart & James 1973, Kikkawa 1982, Recher *et al.* 1991). In the cer-

rado region, Negret (1983) reported that the campo limpo bird community was more similar to that of campo sujo than to that of cerrado *sensu stricto*, which agrees with our results. In Negret's (1983) study, the similarity values for the bird communities of the pairs campo limpo-campo sujo and campo sujo-cerrado *sensu stricto* were almost equal. These results differ from ours because campos sujos were very similar to campo limpo and less similar to cerrado *sensu stricto*.

Bird species abundance is strongly associated to floristic and structural habitat features (Rotenberry & Wiens 1980, Bibby *et al.* 1985) and similar associations may explain the diverse patterns of bird distribution within the open habitats of the cerrado *sensu lato*. Most habitat generalist species (all those that occurred in 4 habitats and half of those present in 3 habitats) use the herbaceous layer. The herbaceous stratum presents a similar cover along the gradient of open habitats and may facilitate the colonization of a greater range of habitats by some species. However, other structural features such as shrub and tree cover may influence the distribution of species that use mainly the herbaceous layer along an open habitat gradient. Indeed, birds like *Cistothorus platensis*, *Alectrurus tricolor* and *Coryphaspiza melanotis* were restricted to campo limpo and campo sujo. Furthermore, herbs species composition is not the same along the cerrado *sensu lato* gradient (Filgueiras 1991) and probably contributes to the patterns of herbaceous stratum bird species occurrence.

By comparison, most specialists were restricted to cerrado *sensu stricto* and are mainly arboreal species. Some of them presented positive correlations with tree cover along this gradient of open habitats. However, an additional increase in this stratum lead to a decrease in the herb and shrub covers, causing stronger changes in the bird community of SS3, a study site that would be classified as

cerrado *sensu stricto* according to canopy cover criteria (Eiten 1993), but supported an avian community more similar to that of cerrado (Negret 1983). Several common species that use mainly the middle and the lower strata in other cerrado *sensu stricto* areas, such as *Phacelodomus rufifrons*, *Elaenia chiriquensis* and *Melanopareia torquata*, were absent from SS3, in response to the increase in tree cover and/or reduction in shrub and herb cover.

In addition to habitat characteristics, other factors that are commonly associated with bird species composition and abundance in a regional scale, such as floristic composition (Wiens & Rotenberry 1981, MacNally 1990), fire (Woinarski 1990, Woinarski & Recher 1997) and habitat size (Willis 1979, Bierregaard & Lovejoy 1989), may be involved in the distribution of birds in the cerrado *sensu lato* gradient. The patchy distribution of habitats in cerrado may also affect community structure, because the colonization of habitats depends on isolation level (Haas 1995) and edge types between habitat patches (Hawrot & Niemi 1996).

The presence of a mesophytic forest adjacent to SS3 may have contributed to the greater presence and abundance of forest species like *Thlypopsis sordida*, *Veniliornis passerinus* and *Penelope superciliosus*, the latter recorded outside of the survey period. As SS3 and the mesophytic forest were not separated, the home ranges of several species may have included both habitats. A great number of forest birds use cerrado *sensu stricto* stands (Bagno 1998) and most use them only close to forest habitats (Tubelis, pers. observ.). The relatively low arboreal species richness of SS1 and SS2 (compared to SS3) was probably due in part to the fact that these study sites were located at least 600 m away from gallery forests.

In cerrado, a seasonal movement of several species occurs between gallery forests and cerrados *sensu stricto* (Cavalcanti 1992,

Lins 1994). The presence of habitat generalist species in the cerrado *sensu lato* gradient suggests that similar movements may occur among these habitats in response to seasonally available resources. Further, movements among habitats occur daily. Several bird species were seen coming from and/or flying to adjacent habitats. There is a considerable variation in the cerrado *sensu lato* matrix within the cerrado region and this can contribute to species richness and abundance of birds in the open habitats.

Degree of habitat specialization within the cerrado *sensu lato* gradient (Silva 1995, Stotz *et al.* 1996, Bagno 1998) may reflect gradual changes in vegetation and associated resources (e.g., insects) that occur along the gradient. This is highlighted by several transitional vegetation types within this gradient and it probably facilitates the use of adjacent habitats. Resources for birds more abundant in campo sujo may also be available, even in low quantities, in campo limpo and campo cerrado. Use of more than one habitat may be also considered an adaptation to the dynamic of fire disturbance that occurs in the cerrado. The gradual changes in open vegetation in the cerrado landscape may favor temporary occupation of adjacent or closed unburned habitats by birds from burned vegetation with similar structure. Also, this gradual landscape matrix can facilitate dispersion of species through the landscape, contributing partially to the relatively high turnover of open habitats species among places of cerrado (Cavalcanti 1999) and facilitating migration movements within the biome extension.

This study showed that changes in bird communities covaried significantly with changes in the vegetation structure along the gradient of non-wetland open habitats in Distrito Federal. Bird community similarity increased with the increasing similarity in habitat structure. The majority of birds showed preference for one or two habitats.

Despite the observed associations among abundance of some bird species and structural habitat features, knowledge of factors involved in bird occurrence still needs more detailed studies. Forests and edges are important for open habitat birds as well. They contribute to species richness and abundance in cerrado *sensu stricto*, and could receive populations of open habitat birds, for example, during dry periods, as previously observed for some species (Cavalcanti 1992).

As cerrado *sensu lato* becomes prime targets for agricultural fields and pastures (Dias 1993), open habitat birds have been drastically reduced in a large range of the cerrado region. In the State of São Paulo, for example, the loss of cerrado bird species was greater than that of Atlantic forest birds due to the great destruction of cerrado habitats (Willis & Oniki 1992).

Great variation in structure and floristic composition of some open habitats (e.g., Ratter & Dargie 1988), diversified landscape matrices in cerrado, strong habitat preferences by some open habitat birds (this study), and between site turnover (Cavalcanti 1999) suggest that there is considerable variation in the populations of birds within the cerrado. Open habitats are high conservation priorities because they contain several rare, endemic and habitat restricted bird species (Stotz *et al.* 1996). Therefore, it is urgent to increase efforts to protect more localities in the cerrado region.

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APPENDIX. Relative abundance (individuals per sample) of bird species on the study sites. CL = campo limpo, CS = campo sujo, CC = campo cerrado, SS = cerrado sensu stricto (numbers after each class represent site). Parameters of the chi-squared test, for $gl = 1$, comparing frequency of most frequent species in grassland habitats (CL + CS) and in habitats with denser woody layer (CC + SS1 + SS2). The column H indicates if a species was more frequent in grassland (G), in habitats with denser woody layer (W) or presented no significant difference between them (ns). Endemic species of cerrado are indicated by an asterisk (*). Nomenclature and sequence of bird species follow Stotz *et al.* (1996).

Species	Study sites									χ^2 test		
	CL1	CS1	CS2	CC1	CC2	SS1	SS2	SS3	χ^2	P	H	
<i>Crypturellus parvirostris</i>	0.34	0.08	0.21	1.30	0.90	1.14	1.36	0.44	35.73	<0.01	W	
<i>Rhynchotus rufescens</i>	0.91	0.75	1.25	0.63	1.15	0.56	0.33	0.19	6.08	0.013	G	
<i>Notbura maculosa</i>	0.97	0.25	0.88	0.10	0.05	0.08	0.11	0	27.34	<0.01	G	
<i>Taoniscus nanus*</i>	0.06	0.08	0	0	0	0	0	0				
<i>Elanus leucurus</i>	0	0	0	0.10	0	0.17	0.22	0				
<i>Heterospizias meridionalis</i>	0	0.21	0.13	0	0	0	0	0				
<i>Buteo albicaudatus</i>	0	0	0	0.23	0.10	0	0	0				
<i>Buteo magnirostris</i>	0	0	0	0	0.05	0.11	0.14	0.19	6.00	0.01	W	
<i>Caracara plancus</i>	0	0	0.17	0.10	0.20	0	0.03	0				
<i>Milvago chimachima</i>	0	0	0	0.03	0.05	0.03	0	0				
<i>Herpetotheres cachinnans</i>	0	0	0	0.07	0	0	0	0				
<i>Falco femoralis</i>	0	0	0	0.20	0.25	0	0.06	0				
<i>Falco sparverius</i>	0.03	0.04	0	0	0	0	0	0				
<i>Cariama cristata</i>	0	0	0	0.13	0.20	0.44	0.39	0	12.82	<0.01	W	
<i>Columba picazuro</i>	0	0	0	0.57	0.10	0.53	0.50	0.50	21.26	<0.01	W	
<i>Aratinga aurea</i>	0	0	0	0	1.00	0.44	0.53	0.06				
<i>Brotogeris chiriri</i>	0	0	0	0	0.20	0.83	0.22	0.39				

APPENDIX. Continuation.

Species	Study sites								χ^2 test		
	CL1	CS1	CS2	CC1	CC2	SS1	SS2	SS3	χ^2	P	H
<i>Amazona aestiva</i>	0	0	0.58	3.07	1.10	5.39	1.94	0.72	34.55	<0.01	W
<i>Amazona xanthops*</i>	0	0	0.17	0.07	0	0	0.17	0			
<i>Coccyzus melacoryphus</i>	0	0	0	0.03	0	0	0	0			
<i>Piaya cayana</i>	0	0	0	0	0	0	0	0.06			
<i>Tyto alba</i>	0	0	0.04	0	0	0	0	0			
<i>Otus choliba</i>	0	0	0	0	0	0.06	0	0			
<i>Speotyto cunicularia</i>	0.66	0.17	0.08	0	0.20	0	0	0	2.81	0.09	ns
<i>Eupetomena macroura</i>	0	0.04	0.13	0	0	0	0	0			
<i>Colibri serrirostris</i>	0.78	1.13	0.79	1.40	0.50	0.44	0.83	0.14	2.40	0.12	ns
<i>Chlorostilbon aureoventris</i>	0	0	0	0	0	0	0	0.06			
<i>Amazilia fimbriata</i>	0	0	0	0.30	0.10	0.83	0.78	0.81	40.31	<0.01	W
<i>Amazilia versicolor</i>	0	0	0	0	0	0	0.03	0.08			
<i>Helictin bilophum</i>	0.03	0.50	0.42	0.33	0.15	0	0.11	0	3.68	0.055	ns
<i>Nystalus chacuru</i>	0	0	0	0.30	0.45	0.44	0.42	0.03	26.81	<0.01	W
<i>Ramphastos toco</i>	0	0	0	0.13	0	0.17	0.17	0.08	7.46	<0.01	W
<i>Melanerpes candidus</i>	0	0.17	0.17	0	0	0	0	0			
<i>Picoides mixtus</i>	0	0	0	0.07	0.05	0.17	0.03	0	7.80	<0.01	W
<i>Veniliornis passerinus</i>	0	0	0	0	0	0	0	0.14			
<i>Colaptes campestris</i>	0	0.88	1.79	0.97	1.50	0.61	0.97	0	0.00	0.99	ns
<i>Dryocopus lineatus</i>	0	0	0	0.07	0	0.22	0	0.06			
<i>Campephilus melanoleucos</i>	0	0	0	0	0	0.06	0	0			
<i>Lepidocolaptes angustirostris</i>	0	0	0	0.20	0.10	0.69	0.42	0.33	31.74	<0.01	W
<i>Synallaxis albescens</i>	0	0	0.08	0.70	0	0	0.78	0	15.16	<0.01	W
<i>Synallaxis</i> sp.	0	0	0	0.07	0	0	0.17	0			
<i>Phacellodomus rufifrons</i>	0	0	0	0	0	0.19	5.58	0	22.16	<0.01	W
<i>Thamnophilus punctatus</i>	0	0	0	0	0	0	0	0.06			
<i>Thamnophilus torquatus</i>	0	0	0	0	0	0	0	0.03			
<i>Melanopareia torquata*</i>	0	0	0	1.03	0.75	0.94	0.67	0	69.19	<0.01	W
<i>Camptostoma obsoletum</i>	0	0	0	0.83	0.05	1.47	0.89	0.58	63.25	<0.01	W
<i>Suiriri suiriri</i>	0	0	0	0.33	0	3.81	0.28	0	23.98	<0.01	W
<i>Elaenia chiriquensis</i>	0	0	0	2.10	1.90	2.33	2.33	0	44.90	<0.01	W
<i>Elaenia cristata</i>	0	0.17	0	0.63	0.65	0.94	0.81	0.31	30.2	<0.01	W
<i>Elaenia flavogaster</i>	0	0	0	0.20	0.10	0.42	0.30	0.28	33.68	<0.01	W

APPENDIX. Continuation.

Species	Study sites								χ^2 test		
	CL1	CS1	CS2	CC1	CC2	SS1	SS2	SS3	χ^2	P	H
<i>Elaenia spectabilis</i>	0	0	0	0.13	0	0	0.11	0.06			
<i>Elaenia spp.</i>	0	0	0	0	0.05	0	0.19	0			
<i>Culicivora caudacuta</i>	0.84	0.63	1.63	0.57	0.70	0	0	0	12.53	<0.01	G
<i>Tolmomyias sulphureus</i>	0	0	0	0	0	0	0	0.17			
<i>Myiophobus fasciatus</i>	0	0	0	0.10	0	0.06	0.06	0			
<i>Xolmis cinerea</i>	0	0.25	0.08	0.03	0	0	0	0	7.48	<0.01	G
<i>Xolmis velata</i>	0	0	0	0	0.25	0	0	0			
<i>Alectrurus tricolor</i>	1.31	1.42	1.50	0	0	0	0	0	89.49	<0.01	G
<i>Gubernetes yetapa</i>	0	0.08	0	0	0	0	0	0			
<i>Casiornis rufa</i>	0	0	0	0	0	0	0	0.11			
<i>Syrstes sibilator</i>	0	0	0	0	0	0	0	0.33			
<i>Myiarchus ferox</i>	0	0	0	0	0	0.42	0.17	0.28	6.73	<0.01	G
<i>Myiarchus swainsoni</i>	0	0	0	0	0	0	0	0.11			
<i>Myiarchus tyrannulus</i>	0	0	0	0	0	0	0	0.19			
<i>Myiarchus spp.</i>	0	0	0	0	0	0	0	0.50			
<i>Pitangus sulphuratus</i>	0	0	0	0	0	0	0	0.22			
<i>Megarynchus pitangua</i>	0	0	0	0	0	0	0	0.08			
<i>Myiodynastes maculatus</i>	0	0	0	0	0	0	0	0.08			
<i>Empidonomus varius</i>	0	0	0	0	0	0	0	0.03			
<i>Tyrannus albogularis</i>	0	0	0	0	0	0	0	0.03			
<i>Tyrannus melancholicus</i>	0	0	0	0	0	0	0	0.28			
<i>Tyrannus savanna</i>	0	0.33	0	0	0.10	0	0	0.69	3.21	0.07	ns
<i>Pachyrhamphus polychopterus</i>	0	0	0	0	0	0	0	0.19			
<i>Tachycineta leucorrhoa</i>	0	0.71	0	0.30	0.35	0.08	0	0	0.00	0.93	ns
<i>Progne tapera</i>	0.13	0.04	0.13	0	0	0	0	0			
<i>Notiochelidon cyanoleuca</i>	0	0.08	0	0.10	0	0	0	0			
<i>Alopochelidon fucata</i>	1.31	2.00	0.29	0	0.10	0	0	0	20.52	<0.01	G
<i>Cistothorus platensis</i>	5.41	3.92	5.42	0	0	0	0	0	199.8	<0.01	G
<i>Troglodytes aedon</i>	0	0	0	1.57	0.90	1.78	0.78	0.58	33.81	<0.01	W
<i>Mimus saturninus</i>	0	0	0	0.10	0	0	0	0			
<i>Turdus amaurochalinus</i>	0	0	0	0	0	0	0	0.06			
<i>Turdus leucomelas</i>	0	0	0	0	0	0	0	0.94			
<i>Poliopitila dumicola</i>	0	0	0	0.07	0	0.17	0.06	0.17			

APPENDIX. Continuation.

Species	Study sites								χ^2 test		
	CL1	CS1	CS2	CC1	CC2	SS1	SS2	SS3	χ^2	P	H
<i>Ammodramus humeralis</i>	0.59	1.83	1.46	1.23	1.30	0	0.42	0	13.53	<0.01	G
<i>Sicalis citrina</i>	0.25	0.42	0.04	0.30	0	0	0	0	4.81	0.03	G
<i>Sicalis luteola</i>	0	0.08	0	0.23	0.10	0	0.06	0			
<i>Emberizoides berbicola</i>	2.31	2.17	3.00	1.13	2.25	0.08	0.75	0	47.7	<0.01	G
<i>Volatinia jacarina</i>	0	0.08	0.08	0	0	0.06	0.17	0			
<i>Sporophila bouvreuil</i>	0	0.38	0.42	0	0	0	0	0	11.78	<0.01	G
<i>Sporophila caerulea</i>	0.03	0	0	0	0	0	0	0			
<i>Sporophila plumbea</i>	0.03	0.25	0.17	1.10	0.05	0	0.44	0	0.10	0.74	ns
<i>Coryphaspiza melanotis</i>	0.22	0.25	0	0	0	0	0	0	16.78	<0.01	G
<i>Coryphospingus cucullatus</i>	0	0	0	0	0	0	0	0.39			
<i>Saltator atricollis*</i>	0	0	0	0	0	0	0.06	0			
<i>Passerina caerulea</i> *	0	0.04	0	0	0	0	0	0			
<i>Neothraupis fasciata*</i>	0	0	0	1.63	1.90	0.83	2.58	0	29.73	<0.01	W
<i>Cypsnagra hirundinacea*</i>	0	0.75	0.96	1.07	1.45	0	0	0	0.76	0.38	ns
<i>Thlypopsis sordida</i>	0	0	0	0	0	0	0	0.06			
<i>Hemithraupis guira</i>	0	0	0	0	0	0	0	2.86			
<i>Piranga flava</i>	0	0	0	0	0	0	0	0.28			
<i>Thraupis sayaca</i>	0	0	0	0	0	0	0	0.28			
<i>Euphonia chlorotica</i>	0	0	0	0	0	0	0	0.14			
<i>Tangara cayana</i>	0	0	0	0	0	0	0	0.50			
<i>Dacnis cayana</i>	0	0	0	0	0	0	0	0.28			
<i>Parula pitiayumi</i>	0	0	0	0	0	0	0	0.25			
<i>Basileuterus flaveolus</i>	0	0	0	0	0	0	0	0.39			
<i>Basileuterus hypoleucus</i>	0	0	0	0	0	0	0	0.5			
<i>Cyclarhis gujanensis</i>	0	0	0	0	0	0	0	0.22			
<i>Vireo olivaceus</i>	0	0	0	0	0	0	0	0.19			
<i>Cyanocorax cristatellus*</i>	0	0	0	1.90	1.10	4.22	4.58	2.47	48.57	<0.01	W

